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RESEARCH STATION
CHESHUNT, HERTS.

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(FORTIETH YEAR)

1954

NURSERY & MARKET GARDEN INDUSTRIES
DEVELOPMENT SOCIETY, LIMITED

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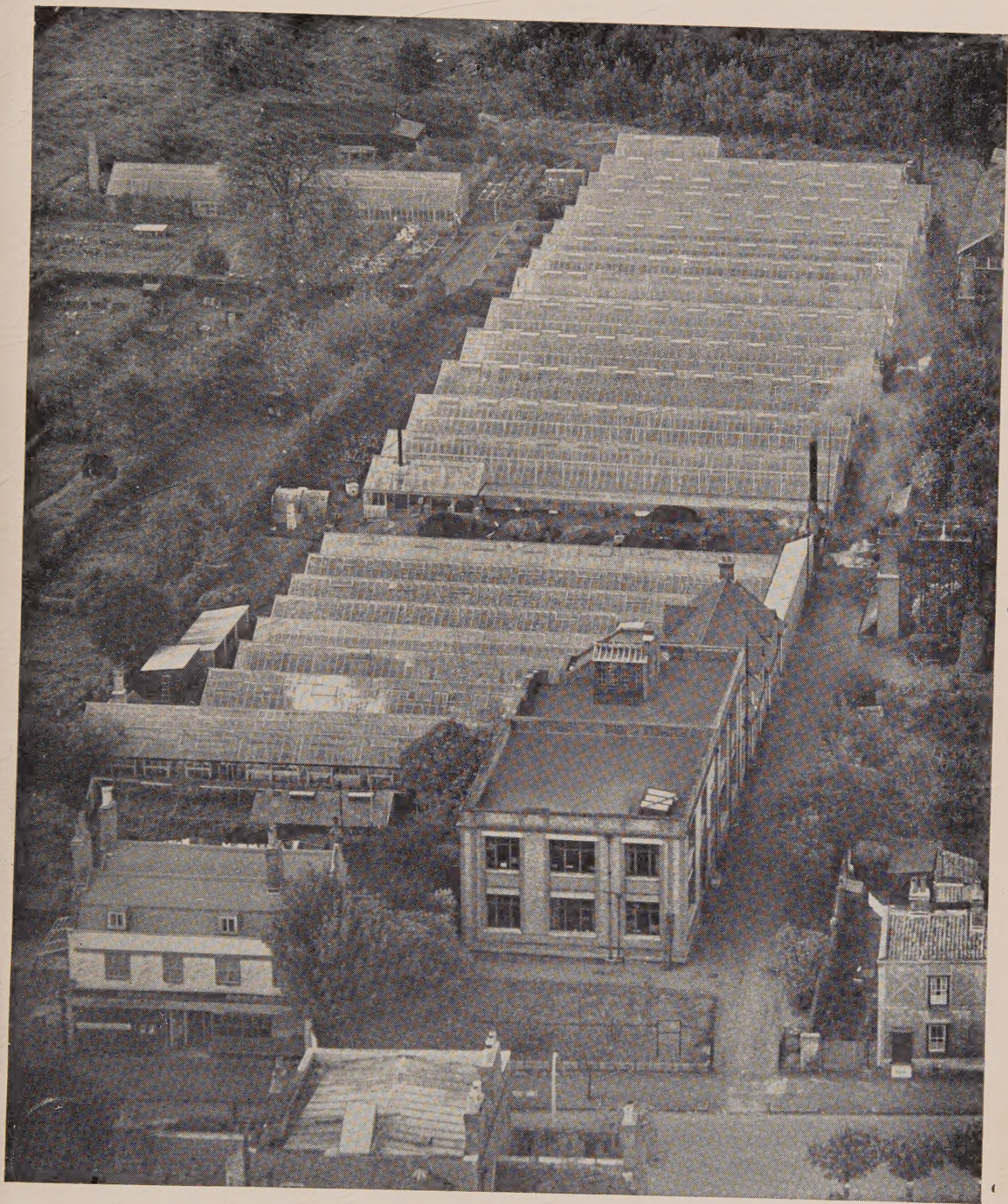
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THE LITTLEHAMPTON GAZETTE

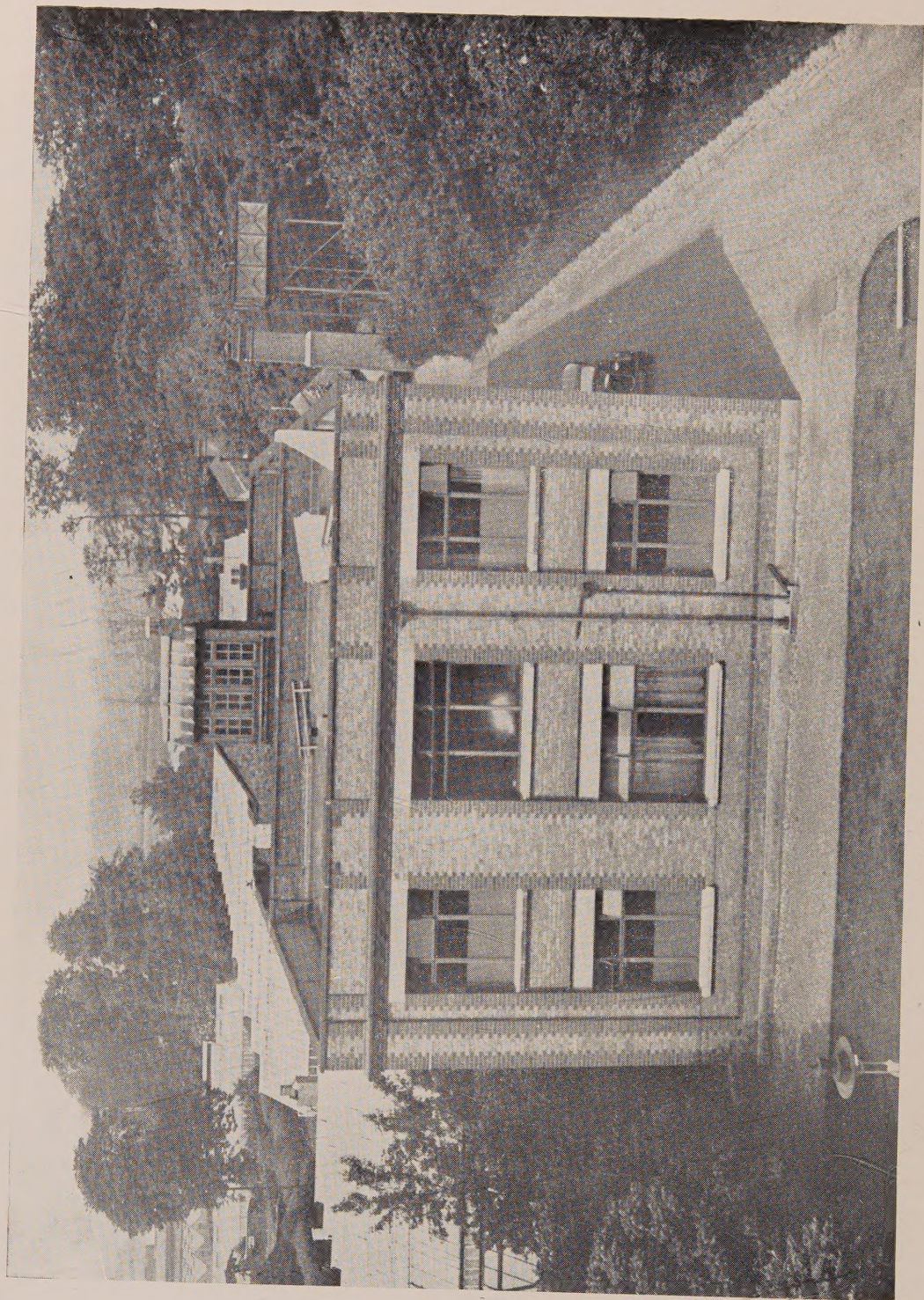
37 BEACH ROAD

LITTLEHAMPTON

1956



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Diagram showing arrangements of Experimental Plots, 1954

Introduction

It is with very mixed feelings that we introduce the final report on the work at Cheshunt, because although we are looking forward eagerly to our new laboratories at Littlehampton we must be forgiven a certain nostalgia at leaving what has been our home for so many years, and where we made so many friends in the glasshouse industry.

Our new research station will soon be ready for occupation, and already a crop of tomatoes has been taken from the cucumber block, the three tomato blocks, the carnation block and the pair of houses so kindly presented to us by the Tomato and Cucumber Marketing Board.

Unfortunately, although the majority of the scientific staff of the Cheshunt Research Station will be transferred to Littlehampton, the Ministry has decided to create a new body to take charge of the new institute. This will be called the "Glasshouse Crops Research Institute" registered under the Company's Act. This means that the old society—The Nursery and Market Garden Industries' Development Society Ltd.—must be wound up, a task which is being carried out by the president, Mr. L. C. Madsen, and the auditor, Mr. G. Copley. The old station at Cheshunt is being sold and the proceeds will go towards the cost of constructing the new buildings.

The success of the Cheshunt Research Station has been very largely due to the close co-operation between grower and scientist. We hope that our transfer to Sussex will make no difference to this and that we will continue to enjoy the confidence and support of our old friends in the industry.

GLASSHOUSE EXPERIMENTS

Plant Density and Crop Yield of Tomatoes

The experiment started in 1952 was continued again in 1954. By reducing the number of plants from 16,000 to 8,000 the crop yield of Potentate was reduced by 20%, and of E.S.5 by 6.5%. Stopping half the plants at five trusses and then removing them after cropping had no effect upon crop yield.

Pruning and Training

In House 9 there was an experiment to demonstrate the advantage of removing all side shoots when they were very young. In two plots the laterals were removed before they were three inches long, in two others they were allowed to grow to a length of 6 or 7 inches before removal. The early removal of the side shoots increased the yield some 18%.

Deficiency Plots

The historic deficiency plots in House 4 are recorded for the last time. The plots receiving no potash yielded 36% of blotchy fruit.

The Omission of Lime and Phosphates

These experiments have been continued for seven years. They indicate that the tomato crop requires little phosphate or lime provided they are supplied in the propagating soil.

Potentate and its Hybrids

Trials of various generations of tomato crosses involving Potentate were continued. The striking feature, as might be expected, was the greater vigour of growth shown by the F.1 generations.

Cucumbers

The trials involved ways of preparing the beds. The outstanding result was the greater yield from beds where the loam and horse manure were laid down in layers instead of being mixed intimately together. An experiment in soil warming gave an increase of 17% in favour of the process.

PLANT PATHOLOGY

Didymella Stem Rot

A further experiment was carried out in House 1. An attempt was made to test the efficiency of 2% formaldehyde in eliminating *Didymella lycopersici* from infected soil but no conclusions could be drawn since only a very small number of plants became infected on the untreated control plots. Soil treated with formaldehyde proved, however, much less susceptible to reinfection by *Didymella lycopersici* than steamed soil. A heavy dressing of stable manure dug in before steaming did not produce any significant difference in the amount of disease when compared with plots receiving a normal dressing. Mulching steamed soil with maiden loam before inoculation with the fungus gave a large reduction in infection. Pricking maiden loam into the surface layers of steamed soil also reduced the number of basal lesions significantly.

Tomato Root Investigations

A comparison was made between the rhizosphere floras of two tomato varieties growing in the glass-house border in two different plots. The method of sampling differed somewhat from that used previously and did not entail the uprooting of the plants. Soil samples were taken midway between rows (*i.e.* about 18in. from the main stems) at a depth of 3-6in. Rhizosphere-soil samples were taken at the same depth but only 3in. from the plant stems, and the roots separated from the rhizosphere-soil samples were shaken free of soil and used for root surface estimations. The two varieties used were Potentate and E.S.5 and Plot A had been left unsteamed for five years and Plot B for two years.

The numbers of soil fungi were considerably higher in Plot A throughout the year, as were numbers of actinomycetes, which also appeared to vary less in numbers in this plot than in Plot B. The difference in bacterial numbers from the two plots was comparatively small. The numbers of fungi from the rhizosphere-soil in Plot A tended to be higher for plants of E.S.5, and for this variety fungal numbers remained fairly constant, whereas in Potentate there was a drop in numbers from August onwards. In Plot B, E.S.5 again gave higher numbers of fungi in rhizosphere-soil, and in this plot fungal numbers rose to a maximum in June and then fell. Fungi on Potentate also rose to a maximum but the fall was somewhat later.

Root surface fungi in Plot A showed a steep rise in numbers on Potentate roots from May to August, and a sharp drop in September. Fungi on E.S.5 roots showed slower rise in numbers and the decrease in numbers was later. In Plot B there were more fungi and a steeper rise in numbers on the roots of Potentate than in Plot A, whereas E.S.5 showed no large increase, and numbers towards the end of the season were lower than on Potentate in the same plot and on E.S.5 in Plot A.

Numbers of actinomycetes showed an increase throughout the season in rhizosphere-soil in Plot A for both varieties, E.S.5 giving higher numbers than Potentate. The root surface flora in Plot A showed similar trends. In Plot B numbers tended to be lower than in Plot A and there was less varietal difference in the rhizosphere-soil numbers. The root surface numbers in Plot B were very high on Potentate roots in mid-season, although on E.S.5 numbers remained lower than in Plot A.

Bacterial numbers in rhizosphere-soil were higher on E.S.5 for both plots. In Plot A numbers generally fell from the beginning of the season onwards, but in Plot B no definite trend in numbers was noted. The root surface floras however showed a rise from the beginning of the season onwards in Plot A, with the numbers on E.S.5 again higher than Potentate. In Plot B numbers were very irregular.

Bacteria isolated from the seven plots used for rhizosphere studies in 1953 were divided into nutritional groups similar to those described by Taylor (Proc. Soc. Appl. Bact. vol 14, 1951). Bacteria used were isolated from the soil, outer rhizosphere and inner rhizosphere in June and October. The results can be summarised as follows.

The habitat from which the bacteria were isolated had a greater influence on the proportion of the groups present than did the soil treatments on the different plots, except in one case noted below.

Differences in bacterial groups which appeared to be due to soil treatment are apparent only in the soil and do not seem to be reflected in the rhizosphere population nor do they persist until the end of the season.

The proportion of bacteria with only inorganic nutritional requirements is higher in the inner rhizosphere than in the other two habitats, and those bacteria with complex requirements are most commonly found in the soil. But in the plot which had not been steamed for several years the bacteria with the most complex requirements are more numerous in the rhizosphere counts than in soil and those needing only inorganic nutrients are approximately equally distributed in the three habitats.

Bacteria needing inorganic salts only, and those requiring inorganic salts plus amino-acids were dominant in the populations isolated from the three habitats in most of the different plots.

Cucumber Mildew

Investigations on cucumber mildew have been commenced. One of the most interesting aspects of this fungus is the problem of its method of survival through the winter. There are only two records of a perfect stage—both identified as *Erysiphe cichoracearum*—being found in cucumber in this country so that the possibility of survival in this stage is very unlikely. The ordinary stage cannot survive apart from the living plant according to many workers and there are at least three months of the year in which no cucumbers are grown and during which the houses are normally cleaned out and fumigated against red spider, etc. The most likely method of survival is therefore by means of an alternate host plant but such a plant has never been recorded. A survey has been made of mildews on common nursery weeds and on other glasshouse plants which are kept through the winter such as *Cineraria* and *Chrysanthemum*. Several of these mildews have been preserved through the winter on other hosts and, when conditions permit, large scale cross inoculations will be carried out to discover if any of these weeds can be infected by mildew from cucumber or vice versa. The problem of the isolation of such experiments with an air-borne disease such as powdery mildew, has been considered and it has been found that both cucumber and the mildew can survive when grown isolated under plastic bags.

In experiments in chemotherapy it was shown, subject to confirmation, that treatment of virus infected tomato seed with saturated 2-chlorophenoxyacetic acid for six days followed by rinsing and drying resulted on regermination in no virus being present at incipient germination. Related acids freed a few chrysanthemum plants from chrysanthemum flower distorting virus. The incubation period of floral symptoms of chrysanthemum flower distorting virus disease was not more than six months.

ENTOMOLOGY

Red Spider Mite (*Tetranychus telarius* L)

Further evidence has been obtained experimentally to confirm that female mites cease forthwith to deposit eggs when deprived of food.

The incubation period of the egg and the duration of each of the three developmental instars has been recorded at constant temperatures respectively of 66 deg. F. and 72 deg. F.

Observations upon the digestive processes in living mites have shown that the so-called "food-balls" contained in the main digestive organ pass periodically into the hind-gut and are finally excreted in the form of dark pellets; the "uratic spheres" are formed in the anterior portion of the latter organ and are excreted in the form of opaque white pellets.

Young tomato pot-plants were infested with mites and kept in a small glasshouse in which the atmosphere was maintained in motion by means of an electric fan continuously over a period of seven weeks; an estimation of the degree of infestation at the end of this period showed no appreciable difference from that obtaining upon similar plants kept in the stagnant atmosphere of an adjoining glasshouse.

Greenhouse White-fly (*Trialeurodes vaporariorum* Westd)

The results of experiments in which adult white-flies were given access to the foliage of *Nicotiana* and Tomato plants growing in soil to which respectively Parathion, its S-ethyl isomer, and its derivative "E.600" (which may be present in crude samples) had been applied, indicated that only the last-named acted upon the insects as a systemic insecticide.

INSECTICIDES AND FUNGICIDES

Fungicides

Certain chlorinated derivatives of salicylanilide have been prepared in the laboratory and examined in *in-vivo* trials for eradicator activity against tomato leaf mould (*Cladosporium fulvum*). None showed outstanding merit although certain anilides of 3:5-dichlorosalicylic acid appeared more effective than salicylanilide against this fungus.

Sprays containing captan (N-trichloromethylthio-tetrahydrophthalimide) at 0.1% were ineffective against tomato leaf mould; manganese dimethyldithiocarbonate at 0.2% showed promise against this disease in preliminary trials.

The values of some 5-hydroxy and 5:8-dihydroxy derivatives of certain substituted quinoxalines for the control of the above disease were examined and these compounds were found devoid of promise.

Additional trials with a proprietary product (Karathane) containing technical 2:4-dinitro-6-capryl phenyl crotonate have confirmed the value of this material for the control of cucumber mildew (*Erysiphe cichoracearum*) but have shown that it is ineffective for the control of red spider on this host.

Acaricides

Parathion and malathion were compared in trials against red spider on cucumbers. When applied as aerosols, parathion was found much more effective than malathion against this pest. Strains of the mite

tolerant to parathion, which became dominant on many nurseries, were also more resistant to malathion. A number of compounds of promise as acaricides have been examined in glasshouse trials but reliable assessment of their relative values proved impossible owing to inadequate facilities for conducting comparative trials.

Insecticides

No loss of tomato plants from wireworm or leather-jacket attack occurred in newly erected houses where there was a moderate wireworm and heavy leather-jacket population prior to treating the soil with a BHC dust.

Analytical

Experiments to assess the possible hazard to workers arising from the absorption of parathion through contact of the hands with recently treated cucumber and tomato plants, were continued.

In conjunction with this work an investigation of the range and variation of "aerosol" deposits in commercial glasshouses was commenced.

The search for improved methods of analysis of the more toxic pesticides has continued.

GENERAL CHEMISTRY

Nitrogenous Fertilizers

Experiments on the preparation and testing of urea-formaldehyde products as slow-acting nitrogenous fertilizers were described in the Annual Report for 1951. In those earlier experiments urea-formaldehyde materials prepared under acid conditions, though showing considerable promise, had failed to give the desired combination of slow steady decomposition in the soil and high ultimate availability.

Alternative methods of preparation of urea-formaldehyde compounds have now been examined. Reaction under alkaline conditions followed by a short acid treatment yielded products showing slightly higher availability in the soil than those prepared entirely under acid conditions. The most promising results, however, were obtained by reaction under mildly acid conditions at a urea/formaldehyde ratio of 0.5 : 1, in contrast to all previous experiments in which urea/formaldehyde ratios of not less than 1 : 1 were employed. Further examination of this type of product is in progress.

While testing samples of plastic waste for the Forestry Commission it was found that the rates of decomposition of urea-formaldehyde materials were markedly influenced by the pH of the soil used. Experiments with two urea-formaldehyde samples in twenty soils having initial pH values ranging from 3.9 to 7.8. showed that the rates of mineralization of nitrogen were inversely related to pH. It was also found that the solubility of urea-formaldehyde samples in buffer solutions increased with acidity in the range of pH 4-8. It may thus be that the initial stages in the breakdown of urea-formaldehyde materials in the soil are chemical rather than biological.

The results suggest that urea-formaldehyde waste products from the plastics industry are of value as nitrogenous fertilizers in acid soils. Thus mineralization of the nitrogen of one sample of plastic waste reached 79% in an acid soil but only 10% in an alkaline soil.

Steam Sterilization

Studies of some factors influencing ammonification in steamed soils have now been concluded. Statistical analysis of the results for twenty glasshouse soils and eighteen field and garden soils shows that the ammonia produced after incubation for three weeks was significantly correlated with the total nitrogen and organic carbon contents of the soils. In both groups of soils the correlations between ammonia produced after steaming and the initial soil pH, % hydrolysable nitrogen and carbon/nitrogen ratio all failed to attain significance at the 5% level. The amount of ammonia produced per unit of soil nitrogen was, however, far less in the glasshouse soils than in the field and garden soils. This difference is considered to be due to the effect of repeated steam sterilization and the maintenance of a high pH on the organic matter of the glasshouse soils.

In contrast to alkaline glasshouse soils, which are readily recolonized by nitrifying organisms after steaming, contamination of acid maiden soils after steaming is not followed by rapid disappearance of the accumulated ammonia unless lime is added. Applications of lime also increase the amount of ammonia produced after steaming ; the response to the addition is small with alkaline and slightly acid soils, but increases with increasing soil acidity.

The effect of steaming on the availability of soil potassium has also been investigated. Laboratory experiments have shown that water-soluble potassium is invariably increased as an immediate result of steaming ; a statistically significant relationship exists between the initial content of water-soluble potassium in soils and the subsequent increase on steaming. Experiments with three glasshouse soils *in situ* have also

shown increased potassium concentrations after steaming both in aqueous extracts and in displaced soil solutions.

Water-soluble and exchangeable manganese have been shown to be increased after steaming. In alkaline glasshouse soils the content of water-soluble manganese is very low, and only small increases have been observed after steaming. In contrast, some acid maiden soils contain considerably increased amounts of water-soluble and exchangeable manganese after steaming. Marked toxicity symptoms have been observed in young tomato plants grown in such soils. The addition of superphosphate intensified the toxicity symptoms and increased the uptake of manganese. The application of lime either alone or with superphosphate improved the appearance of the plants and markedly reduced both the uptake of manganese by the plant and also the levels of water-soluble and exchangeable manganese in the soil.

“ Blotchy Ripening ” of Tomato Fruit

Investigations of certain chemical aspects of blotchy ripening of tomato fruit have been undertaken. A scheme of analysis of the constituents of expressed plant sap has been devised and applied to (1) paired samples of normal and blotchy fruit (Variety “ Potentate ”) from sixteen nurseries (2) the variously coloured portions of the walls of blotchy fruit and (3) fruit at different stages of ripeness.

Marked differences were found in the concentration of certain constituents of sap expressed from blotchy and normal fruit. Thus mean values for total sap solids, sugars, nitrogen and titratable acidity were significantly lower, and pH higher, in blotchy than in normal fruit. The potassium and ash content of the sap of blotchy fruit, and its electrical conductivity, were not significantly lower than in normal fruit.

Analyses of sap expressed from differently coloured areas of the walls of blotchy fruit showed the highest values for total solids, sugars, titratable acidity and nitrogen in the red areas, with progressively lower values in the orange-yellow and yellow-green areas. The converse was true for pH and conductivity.

Preliminary experiments have been made to relate differences in the composition of sap expressed from the variously coloured portions of blotchy fruit to the changes occurring during the normal processes of ripening.

Boron in the Nutrition of Tomatoes

Tomato plants (Variety Potentate) were grown in sand culture at concentrations of 0.2 p.p.m. of added boron. As shown by measurements of height, leaf length and weight, growth of the plants increased with boron concentration from 0 to 0.2 p.p.m.; at a concentration of 2 p.p.m. the effects of boron toxicity were apparent. Chlorosis of the leaves appeared at concentrations up to 0.02 p.p.m. in the main experiment (0.03 p.p.m. in a subsidiary experiment).

The effect of boron deficiency on fruiting was particularly marked. Thus no normal fruit developed at concentrations of boron up to 0.008 p.p.m. in the nutrient solution, and at 0.02 p.p.m. the effects of boron deficiency were more readily apparent in the fruit than in the foliage.

Mineral Deficiencies in Hydrangea

The visual symptoms of some mineral deficiencies of hydrangea have been studied in sand culture, the varieties used being Goliath and King George. Omission of potassium from the nutrient solution resulted in acute interveinal chlorosis of the young leaves such as is normally associated with iron deficiency. The effect of boron deficiency on the flowers was particularly marked, the petals being greatly reduced in size, irregular in shape, and of poor colour and texture.

The plants were less affected by calcium deficiency than were other subjects previously studied in sand culture, but the foliage was badly disfigured by magnesium deficiency during the period of flowering.

Only when at least 4 p.p.m. of aluminium were included in the nutrient solution was it found possible to produce normal green foliage, free from chlorosis. The colour of the blooms was dependent on the concentration of aluminium in the nutrient solution ; “ blueing ” of the flowers was greatly facilitated by the omission of phosphorus or nitrogen.

Uniformity Trials at the Glasshouse Crops Research Institute

Considerable variability was noted in the growth of tomato plants in houses B 1—4 and C 1—4, these having been treated only with stable manure. At the suggestion of the Research Committee soil and leaf samples were collected for analysis from areas of poor and good growth.

In so far as the observed variations in growth of the plants may be related to the availability of plant nutrients, it is likely that shortage of potash was an important factor. Considerable variability in the depth of preparation of the borders was also apparent, however.

PLANT PHYSIOLOGY

Dutch Light Temperatures

Work on this project, carried out in collaboration with the Agricultural Branch, Meteorological Office, was discontinued in May, at the end of the period of liability to frost. Some of the data obtained have formed the basis of a contribution to a meeting of the H.E.A. (and published in *The Grower*) and a brief publication in *Weather*. It was evident that for any further elucidation of the problems involved in the physical protection afforded to the soil and air under unheated Dutch Lights considerably more recording equipment and attention would be required.

Root Growth Studies

Two glass-sided trenches were used for observations on the growth of the roots of one variety of tomatoes in a glasshouse border throughout the season. The effect on the growth of stem and roots of allowing all the laterals to grow, sub-laterals only being removed, was studied, as well as the effect of removing all the laterals.

Root Environment

Soil tensiometers were again installed in a glasshouse border and the trends of soil moisture tension were followed throughout the growing season.

The automatic, pressure-balance, recording tensiometer was tested when attached to porous pots in the soil around potted tomato plants in the glasshouse and the observations compared with those from similar pots attached to mercury-in-glass manometers. A diaphragm-type vacuum gauge was tried out when attached to a porous pot and the tensions indicated by Bourdon-tube and mercury-in-glass manometers attached to porous pots in the glasshouse border were compared.

Preliminary experiments were made on soil moisture control methods.

Obituary

Mr. EDWARD AUGUSTUS BOWLES

Mr. Edward Augustus Bowles died on May 7th, 1954, at Myddelton House, Enfield, just short of his 90th year. He was the youngest son of Mr. Harry Bowles, Chairman of the old "New River Company". He left Cambridge about 1886 to take Holy Orders but his mother persuaded him to remain at home when the second son died. So he helped at Forty Hill Church, where he read the lessons and conducted a night school of some rather tough boys of Enfield Highbury. He also "took up" gardening to such good purpose that he became one of the greatest and best-loved gardeners in this country.

Mr. Bowles' first love was entomology and he never lost interest in insects of all sorts and kinds. He used to say that he owed his enthusiasm for gardening to Canon Ellacombe of Bitton, whose praises he never failed to express. He had a scientific mind, supported by a marvellous memory, but he was always a gardener rather than a scientist. Walking and talking with him in the gardens of Myddelton House was more than an education, it was an inspiration. Here was a great Christian gentleman who loved his garden and all it contained and who wanted to persuade everyone else to do the same.

He had all the artist's love of colour and indeed also of form, as the training of his plants, especially the Ivies testified. His flower paintings have seldom been excelled for he brought not only an artistic rendering but a profound botanical knowledge to their production.

Mr. Bowles represented the county of Essex on the Committee of Management of the Cheshunt Research Station from 1919 until the time of his death. He was a most regular attender at the meetings. His profound learning in so many subjects was of the greatest value to his colleagues, and his wise counsel will be greatly missed, but the lives of all who knew him have been enriched by his influence.

Mr. EDWARD CHARLES GALLOWAY

Mr. Edward Charles Galloway passed away on July 15th, 1954. He was educated at Marlborough College; he played cricket and rugby for his school, and later played rugby for the "Old Boys" for many years. His sporting instincts also took him into the world of amateur boxing, in which he was a good

middleweight. He served in the Queen's Gloucesters in the first world war and later joined the Stock Exchange, but he was out of his element there for his heart was in the country.

Ultimately he left the City and went to nurseries in Cheshunt to study the cultivation of glasshouse crops, especially tomatoes and chrysanthemums. Later he built his own nursery at Low Hill near Broxbourne in Hertfordshire which he maintained up to the time of his death.

Mr. Galloway always took a great interest in the work of the Research Station, and served on the Committee of Management from 1939 to the end as one of the representatives of the Lea Valley Growers.

He held a balanced view on life in general. Any ideas he expressed were based on his own knowledge and as would be expected of a sportsman he was always scrupulously fair.

We will miss his courteous and friendly example.

1. EXPERIMENTAL RESULTS OF 1954

I. TOMATOES

The practice of grading the tomato fruits from the experimental plots, adopted in 1921, was continued :

- A. "Pinks" number 5 to 7 and "Pink and White" 8 to 10 to the lb. These are the best quality of fruit in size, shape and colour ; "Pinks" being slightly larger than "Pink and Whites."
- B. "Whites." These fruits are of good colour but smaller than "Pink and Whites."
- C. "Blues." This grade consists of fruits of good colour but larger and more irregular in shape than Grade A.
- D. "Roughs." Small mis-shapen fruits about the size of cherries.
- E. Blotchy fruits which ripen irregularly.
- F. Fruits showing Blossom End Rot.
- G. Fruits showing the lesions of Streak Diseases.
- H. Fruits showing "Green Back."

(a) Planting Density

An experiment in planting density commenced in 1952 when we compared the crop from densities of 16,000 and 8,000 plants per acre. Although there was little difference in total yield per acre from the two densities, there was a loss of some £91 per acre owing to the slightly lower weight of fruit produced at the beginning of the season.

In 1953 the investigation was extended by comparing the crop from a density of 16,000 plants per acre with one from a similar density at planting time but where half the plants were "stopped" above the fifth truss and then removed after the fruit had been picked. A side-shoot from the adjoining plant, however, was trained into the vacant space. The results showed an increase of some 25% in crop weight in favour of the "stopping" and removal of half the plants after the fifth truss. This was almost too good to be true and so the experiment was repeated in 1954, using the variety E.S.5 in House 3 and Potentate in House 8. In each case there was a comparison of crop yields from densities of 8,000 and 16,000 plants per acre as well as that from a density of 16,000 plants per acre where half the plants were stopped at five trusses and removed when the crop had been picked.

The results are given in Tables 1 and 2.

Reducing the number of plants per acre from 16,000 to 8,000 reduced the Potentate crop about 20%, but in the case of E.S.5 the reduction was only 6.5%. "Stopping" above the fifth truss and removal after picking the fruit had no effect.

It should be remembered, however, that weather conditions made the crop very late and it was obvious that the stopped plants were not taken out too late to make any difference.

The experiment is being repeated at Littlehampton in 1955.

(b) Pruning and Training

In House 9 an experiment was arranged to demonstrate the increase in crop yield which almost invariably occurs when all the side shoots are removed when they are very young.

In two plots, 1 and 5, all the laterals were taken out before they were three inches long. In plots 4 and 8 they were left to grow to a length of six to seven inches before being removed. A yield of 50.65 tons per acre was obtained where the laterals were taken out early, and only 42.76 tons per acre when the laterals were allowed to grow.

Leaving a second shoot to make a second main stem after the sixth truss also reduced the yield as did the practice of allowing alternate laterals to remain and form one truss before they were stopped. The results are given in Table 3.

(c) Deficiency Plots

The historic deficiency plots in House 4 were recorded for the last time ; the results are given in Table 4. As a crop reducer a deficiency of nitrogen is stronger than a deficiency of potash, which again is stronger than a deficiency of phosphate.

The figures for percentage " blotchy fruit " are just as instructive as ever. The plot unmanured since 1916 produced 1.66% blotchy fruit ; that starved for nitrogen 0.50%, and that without phosphate 0.48%. Where potash has been omitted, however, the amount of blotchy fruit was 36.54%.

TABLE I
HOUSE 3. VARIETY E.S.5. PLANTING DENSITY

Plot	Treatment	Crop Weight in Lbs. per Square Yard						Total Tons per Acre	Average Tons per Acre	% Blotchy Fruit
		May	June	July	Aug.	Sept.	Oct.			
1 5	Normal planting : 16,000 per acre ... Ditto ...	0.61 0.05	9.69 5.47	5.70 5.75	2.94 2.86	3.9 4.31	— —	22.93 18.44	49.66 } 38.77 }	0.33 0.43
2 6	Half normal planting : 8,000 per acre ... Ditto ...	0.30 0.09	7.20 5.10	6.34 6.27	2.67 2.88	4.40 3.00	— —	20.91 17.34	45.18 } 37.49 }	0.07 0.60
3	Normal planting : Alternate plants stopped at 5 trusses and removed : shoot taken across to empty string ... Ditto ...									
7		0.08 0.27	6.80 8.45	6.19 5.18	3.09 2.36	3.98 4.01	— —	20.14 20.27	43.50 } 42.68 }	0.21 0.14
4 8	Normal planting : Stopping and removal as in Plots 3 and 7, but no shoot taken across Ditto ...	0.03 0.30	6.26 9.18	7.29 5.66	2.94 3.27	3.49 3.56	— —	20.01 21.97	43.25 } 47.46 }	0.45 0.28

TABLE II
HOUSE 8. VARIETY POTENTATE. PLANTING DENSITY

Plot	Treatment	Crop Weight in Lbs. per Square Yard						Total tons per Acre	Average Tons per Acre	% Blotchy Fruit
		June	July	Aug.	Sept.	Oct.	Nov.			
1 5	Normal planting : 16,000 per acre ... Ditto ...	3.24 1.78	6.42 7.23	3.34 4.24	3.28 5.60	3.55 3.32	2.26 2.31	22.09 24.48	47.74 } 52.90 }	19.56 14.99
2 6	Half normal planting : 8,000 per acre ... Ditto ...	2.15 1.17	5.97 5.22	3.52 2.57	3.08 3.71	3.20 2.18	2.85 1.88	20.77 16.73	44.89 } 36.15 }	22.30 20.75
3	Normal planting : Alternate plants stopped at 5 trusses and removed : shoot trained across to empty string ... Ditto ...									
7		3.12 2.18	6.95 5.94	4.33 3.73	4.49 3.93	3.17 2.40	2.64 3.00	24.70 21.18	53.39 } 45.77 }	17.64 13.59
4 8	As 3 and 7, but no shoot trained across ... Ditto ...	2.07 2.95	7.68 7.32	3.84 4.24	3.55 3.70	2.43 2.74	2.83 2.58	22.40 23.53	48.40 } 50.84 }	15.18 18.82

TABLE III
HOUSE 9. VARIETY AILSA CRAIG. "STOPPING AND PRUNING"

Plot	Treatment	Crop Yield in Lbs. per Plant							Total Tons per Acre	Average Tons per Acre	% Blotchy Ripening
		June	July	Aug.	Sept.	Oct.	Nov.	Total			
1	Remove all laterals before they are 3in. long. Only main stem allowed	0.94	2.19	1.16	1.21	0.89	0.46	6.85	52.04 } 49.25 }	50.65	3.94 1.17
5	Ditto	0.84	1.96	1.36	0.99	0.57	0.76	6.48			
2	As 1 and 5 but take up a second shoot above the 6th truss. All laterals taken out when small	0.78	1.94	1.03	1.06	0.69	0.40	5.90	44.84 } 36.93 }	40.89	1.87 2.68
6	Ditto	0.78	1.62	1.09	0.77	0.58	0.52	4.86			
3	From 6th truss take alternate laterals; stop after 1st truss and remove all other laterals	0.49	2.22	0.96	1.11	0.99	0.55	6.32	48.03 } 33.22 }	40.63	1.89 1.60
7	Ditto	0.41	1.53	0.94	0.74	0.40	0.35	4.37			
4	As 2 and 6, but laterals removed when 6 to 7in. long	0.25	1.95	1.09	1.13	0.66	0.64	5.72	43.48 } 42.03 }	42.76	2.23 1.09
8	Ditto	0.57	1.92	1.11	0.87	0.67	0.39	5.53			

TABLE IV
HOUSE 4. VARIETY AILSA CRAIG

Plot	Treatment	Crop yield in Lbs. per Plant							Total Tons per Acre	% Blotchy Fruit
		May	June	July	Aug.	Sept.	Total	Total		
1	C.A.—Nitrogen	0.29	1.28	0.22	0.21	0.09	2.09	15.89	15.89	0.50
2	Unmanured	0.17	1.18	0.24	0.18	0.05	1.82	13.84		
3	Complete artificial	0.10	1.61	1.03	0.67	0.81	4.22	32.08	32.08	1.66
10	C.A. with horse manure	0.14	1.59	1.16	0.68	0.76	4.33	32.92		
11	C.A. with phosphates	0.15	1.53	1.06	0.78	0.59	4.11	31.24	31.24	0.24 0.48
12	C.A. with potash	0.22	1.67	0.81	0.52	0.42	3.64	27.67		

TABLE V
HOUSES 11 AND 12
VARIETIES : PLOTS 1 AND 4 E.S.1
PLOTS 2 AND 3 L.M.R.1

House	Plot	Treatment	Crop Weight in Lbs. per Plant								Total Tons per Acre	Average Tons per Acre	% Blotchy Ripening
			May	June	July	Aug.	Sept.	Oct.	Nov.	Total			
11	1	Control	0.12	1.39	1.97	0.85	0.50	0.55	0.29	5.67	43.10 } 37.76 }	40.43	0.88
11	2	Ditto	0.01	1.11	1.39	0.78	0.48	0.68	0.52	4.97			1.01
11	3	Lime omitted	0.01	1.29	1.52	0.71	0.35	0.63	0.53	5.04	38.31 } 36.10 }	37.21	0.60
11	4	Ditto	0.05	1.34	1.74	0.74	0.24	0.37	0.27	4.75			2.53
12	1	Phosphates omitted	0.28	1.67	1.51	0.60	0.32	0.40	0.23	5.01	38.07 } 37.01 }	37.54	1.00
12	2	Lime added Ditto	0.02	1.43	1.23	0.60	0.29	0.56	0.74	4.87			1.65
12	3	No lime, No phosphates	0.02	1.65	1.35	0.80	0.44	0.53	0.89	5.68	43.16 } 42.11 }	42.64	0.70
12	4	Ditto	0.18	1.61	1.81	0.86	0.51	0.32	0.25	5.54			0.90

TABLE VI
HOUSE 5. VARIETIES HYBRIDS

Plot	Treatment	Crop Yield in Lbs. per Plant					Total Tons per Acre	% Blotchy Fruit	% Pink and White	% White
		May	June	July	Aug.	Sept.				
1	Ailsa Craig	0.11	1.54	1.13	0.63	1.07	34.05	0.44	62.72	25.00
2	Potentate x a	0.03	1.28	1.36	0.84	1.35	36.94	4.11	58.23	14.19
3	"	0.04	1.16	1.62	0.92	1.28	38.15	6.37	49.20	12.16
4	"	0.05	0.87	1.53	0.67	1.34	33.90	5.60	52.00	11.45
5	x b	0.04	1.25	1.36	0.63	1.50	36.33	4.18	51.66	20.92
6	"	0.01	1.31	1.27	0.72	1.34	35.34	3.23	45.81	22.16
7	"	—	1.03	1.46	0.53	1.59	35.04	1.74	52.06	11.93
8	x c	0.01	1.47	1.64	0.85	1.56	42.02	1.26	60.04	16.09
9	"	0.01	1.07	1.78	0.93	1.38	39.29	4.13	48.16	15.68
10	"	—	0.74	1.82	1.04	1.64	39.82	1.91	53.44	17.75
11	x d	0.01	1.05	1.93	1.20	1.64	44.31	1.20	60.55	21.10
12	Fordhook x Potentate	—	1.09	1.77	0.60	0.66	31.30	4.12	30.10	8.24
13	Potentate x e	0.03	0.93	1.39	0.63	1.14	31.31	3.38	43.44	12.87
14	"	0.02	1.49	1.55	0.78	1.36	39.52	3.09	50.76	19.61
15	"	0.05	1.39	1.79	1.06	1.17	41.49	0.72	58.42	20.71
16	x f	0.04	1.15	1.42	0.92	1.01	34.50	2.20	49.13	22.90
17	"	0.05	1.32	1.76	0.88	1.20	39.60	3.84	53.85	20.15
18	"	0.01	1.39	1.56	1.14	1.23	40.50	3.56	51.06	20.07
19	x g	0.02	1.13	1.69	0.90	1.12	36.94	8.23	47.93	14.00
20	"	0.05	1.53	1.33	0.89	1.28	38.61	4.92	51.57	14.37
21	"	0.07	2.08	1.92	1.03	1.15	47.51	2.57	56.96	20.80
22	Ailsa Craig	0.03	1.55	1.25	0.89	0.81	34.43	9.93	58.49	27.16

TABLE VII
HOUSES 7 AND 10. HYBRIDS

House	Plot	Variety	Crop Weight in Lbs. per Plant							Total Tons per Acre	% Blotchy Fruit	% Pink and Pink & White	% White
			June	July	Aug.	Sept.	Oct.	Nov.	Total				
7	1	Potentate x e	1.23	2.24	1.27	1.35	1.32	0.61	8.02	60.95	3.61	54.86	17.08
	2	E.S.1 x h...	1.18	2.34	1.44	1.26	0.99	0.88	8.09	61.48	4.20	57.97	20.53
	3	Potentate x a	0.83	2.58	1.56	1.56	1.24	0.75	8.52	64.75	10.10	48.59	13.29
10	1	Potentate x b	0.30	2.04	0.97	0.71	0.69	0.82	5.53	42.03	9.59	41.78	18.08
	2	Delicious x i	0.41	2.04	0.82	0.81	0.68	0.65	5.41	41.10	8.69	44.18	18.86
	3	Potentate x f	0.40	2.38	0.92	0.90	0.68	0.62	5.90	44.84	10.68	39.65	22.55
	4	j x Potentate	0.06	1.65	1.15	1.35	0.78	0.82	5.81	44.15	7.23	37.35	21.00
	5	Potentate x k	0.16	2.16	1.48	1.67	0.66	1.01	7.14	54.26	7.71	42.57	20.86
	6	a x Potentate	0.06	1.97	1.01	1.17	0.81	0.81	5.83	44.31	13.90	37.91	11.83
	7	Potentate x m	0.44	2.28	1.06	1.06	0.78	0.65	6.27	47.66	7.34	49.60	24.09
	8	f x Potentate	0.80	2.16	1.20	1.02	0.71	1.07	6.96	52.90	6.52	55.88	19.40

TABLE VIII
CUCUMBER EXPERIMENTS. VARIETY : BUTCHER'S DISEASE RESISTER

House	Plot	Treatment	Crop Yield in Lbs. per Plant								Total Tons per Acre	Average Tons per Acre	Total Flats per Foot
			March	April	May	June	July	Aug.	Sept.	Total			
D	2	Bed of loam and manure mixed	0.23	15.46	9.16	6.75	6.19	9.27	1.12	48.18	72.27 } 59.09 }	65.68	1.51 1.23
	4	Ditto	0.32	12.5	7.73	5.85	5.43	6.91	0.65	39.39			
	3	Bed of loam and manure in layers	0.09	15.20	9.90	6.43	5.95	10.95	2.24	50.76	76.14 } 68.16 }	72.15	1.59 1.42
E	5	Ditto	0.45	14.08	9.06	5.81	6.01	8.43	1.60	45.44			
	2	Bed of loam and manure in layers	0.8	14.02	8.48	4.66	5.56	8.22	2.86	43.88	65.82 } 68.85 }	67.34	1.37 1.43
	4	Ditto	—	13.35	8.72	5.78	6.32	8.19	3.54	45.90			
F	3	Bed of loam and manure mixed	0.7	10.12	7.80	4.88	4.69	6.69	1.97	36.22	54.33 } 64.73 }	59.53	1.13 1.35
	5	Ditto	0.07	13.08	8.52	5.31	6.56	7.39	2.22	43.15			
	2	Bed of loam and manure mixed	0.60	11.59	8.33	5.40	6.31	6.67	2.00	40.90	61.35 } 67.46 }	64.41	1.28 1.41
G	4	Ditto	0.24	12.14	9.77	6.45	7.22	6.78	2.37	44.97			
	3	Bed of loam and manure on chalk base	0.06	12.32	8.09	5.64	5.24	5.21	2.69	39.65	59.48 } 58.86 }	59.17	1.24 1.23
	5	Ditto	0.19	9.42	8.90	5.66	6.33	7.13	1.61	39.24			
6	6	Bed of loam and manure mixed on base of bricks	0.22	12.91	9.94	6.29	6.68	6.45	1.86	44.35	66.53	66.53	1.39
	1	Bed of loam and manure mixed on base of bricks	0.31	12.50	9.71	6.24	5.03	3.16	0.75	37.70			
	3	Bed of loam and manure mixed : Control	0.15	13.46	8.63	5.07	4.68	6.60	0.99	39.58	56.55 } 59.37 }	57.96	1.18 1.24
2	2	Ditto	0.24	11.22	9.57	8.21	6.90	6.79	0.69	43.62			
	4	As 1, but soil warmed	0.12	15.16	9.80	8.16	6.59	5.10	1.57	46.50	69.75 }	67.59	1.45
	4	Ditto	0.12	15.16	9.80	8.16	6.59	5.10	1.57	46.50			

(d) The Omission of Lime and Phosphates

The 1954 results of these experiments started in 1947 are given in Table 5. The crop was reduced by omitting either lime or phosphate singly, but the omission of both together made little difference.

These experiments lasting seven years point to the fact that the tomato requires little lime or phosphate provided it is supplied in the soil mixture used for propagating the young plants.

(e) Tomato Hybrids

Trials with various generations of tomato crosses involving Potentate were continued. The results are shown in Tables 6 and 7.

Table 6 gives the yields obtained from F1, F2 and F3 generations of six crosses having Potentate as the mother. It will be seen there was little difference in crop yield between the different generations except occasionally. In two cases only was the F1 yield greatest. In four cases the yield from the F2 was greater than that from the F1, and in three cases the F3 produced the highest yield. In every case, however, the F1 looked better and produced a stronger growth than either the F2 or the F3, and usually the F3 showed a decidedly increased susceptibility to mosaic disease.

In Houses 7 and 10—Table 7—a number of F2 generations are compared. Considerable variation in crop yield will be observed but the habit of all the crosses was vigorous without exception. The actual names of the parents other than Potentate have not been disclosed, since there is nothing outstanding to record and at this stage the results could be misleading.

II. CUCUMBERS

The cucumber experiments were concerned with the manner in which horse manure and loam were used in the preparation of the beds and the type of base under the beds.

In Houses D and E half the beds consisted of two parts loam and one part stable manure, taking care to mix the two together very thoroughly; in the other plots the same amounts of horse manure and loam were used but they were laid down in layers, sandwiching the manure between layers of loam.

The variety used was Butchers' Disease Resister and the results are given in Table 8. It will be seen that an appreciable increase in yield occurred in both houses, where the beds consisted of layers of loam and horse manure. Beds prepared by mixing loam, 2 parts, and horse manure, 1 part, were placed on the floor of the house in the usual way and served as controls. Similar beds were placed on a base of chalk and rammed hard, others were made up on a brick base. There was little difference in the crop yields although the lowest came from the beds over a layer of chalk.

In House G two beds were warmed by circulating hot water through narrow pipes laid beneath them. The water was heated in a gas boiler placed outside the house. Temperatures of 85 deg. to 90 deg. F. were maintained. There was an increased yield of some 17% in the warmed beds over the controls.

II. PLANT DISEASES

I. DIDYMELLA STEM ROT

By P. H. WILLIAMS and JUDITH HACK

Experiments in House 1

The experiments in House 1 were continued. They were designed to ascertain :—

- (1) The use of formaldehyde in eliminating *Didymella lycopersici* from the soil after an infected crop.
- (2) Whether soil treated with formaldehyde is as readily reinfected by the fungus as is steamed soil.
- (3) The effect of a heavy dressing of stable manure applied before steaming on the disease.
- (4) Methods for protecting steamed soil from reinfection.

Thirty-two plots, each containing 20 plants, were laid out as in 1953, being divided into four blocks of eight treatments each. Treatments were applied as follows :—

- (1) Soil treated with formaldehyde 2% at the rate of 5 gallons per square yard. The plots were not inoculated with *D. lycopersici*.
- (2) Formaldehyde as above, but the plots inoculated later.
- (3) Untreated.
- (4) Soil steamed, and then left without inoculation.
- (5) Soil steamed, 60 tons of stable manure applied when steaming : later the plots were inoculated.
- (6) Soil steamed and later inoculated.
- (7) Soil steamed, mulched with maiden loam, and later inoculated.
- (8) Soil steamed, maiden loam pricked into the surface and later inoculated.

Stable manure at 30 tons per acre was dug into all plots before treatment except those in treatment 5.

Treatments were randomised within each block with the exception of treatments 1, 2 and 3. Since treatments 1 and 3 were designed to test the effect of formaldehyde on eliminating *D. lycopersici*, it was necessary to apply them to plots which had shown a high level of disease in 1953. Plots chosen for treatment 2 had been control plots or had shown a low level of disease in 1953 so as to minimise the effect of possible survival of the fungus after formaldehyde treatment. It proved possible to arrange plots fulfilling these requirements so that they were adjacent, a fact which made steaming the remainder of the experimental area more convenient.

The soil was steamed on November 26th, 1953 and formaldehyde applied on December 2nd. As before, the plots were delimited by strips of asbestos sheet. A mulch of maiden loam about $\frac{1}{2}$ in. thick was placed on the surface of the plots receiving treatment 7 on December 14th, the same quantity having been pricked in on those receiving treatment 8 on December 4th. The steamed plots were flooded on December 8th and 11th, and those treated with formaldehyde on December 15th and 16th. The soil was inoculated with spores of *D. lycopersici* on December 23rd. Subsequent cultural treatment conformed with normal practice. Planting with the variety Potentate was carried out on March 8th and 9th and plants finally removed on October 25th.

The first diseased plant found was on April 4th, an interval after planting exactly the same as in the previous year. The subsequent course of the disease was, however, somewhat different from that in 1953. A larger proportion of plants became diseased and there was a more rapid build-up of disease to a high peak at the end of May. Stem lesions were also more abundant. Doubtless this was the result of the cold, wet season.

RESULTS

(1) Formaldehyde treatments

Only 1 plant out of 80 developed a basal lesion on the plots treated with formaldehyde after bearing a heavily infected crop. Unfortunately the value of formaldehyde for eradicating *D. lycopersici* could not, however, be assessed from this experiment since only 3 plants became diseased on the untreated control

plots. This result is, however, interesting since it would seem that careful removal of the diseased plants combined with burying the surface soil sufficed to eliminate almost all infection. A previous failure of *D. lycopersici* to overwinter in a cucumber house has been reported (3). Phillips (1) has reported pot experiments in Jersey where plants were treated with soil taken from fields in which stem rot had been severe. When plants were treated with soil taken immediately after removal of the crop, one third to one half of the experimental plants became diseased. When soil was taken from the same areas nine months later, few or none of the treated plants were lost. On the other hand, we have reported that when tomatoes were planted in pots which had been used in an experiment the previous year about 10% became infected. In this case the soil remained undisturbed, only the top layers being removed and replaced. It is possible, therefore, that digging or otherwise cultivating the soil may play an important part in this disappearance of the disease by burying the highly contaminated surface layers.

When soil was reinoculated with *D. lycopersici* after treatment with formaldehyde, 26 plants became infected compared with 56 on the reinoculated steamed plots. Soil treated with formaldehyde is thus much less susceptible to reinoculation than steamed soil.

(2) Stable Manure

In our experiments in 1953 (2) we found that digging in stable manure at the rate of 30 tons per acre did not effect the amount of disease, despite the fact that in pure culture the addition of stable manure to soil leads to a great increase in growth of the fungus. In this year's experiments dressings of 30 and 60 tons per acre were used but there was no significant difference in the amount of disease.

(3) Maiden loam

Since the establishment of *D. lycopersici* in steamed soil may in part be due to lack of competition from soil organisms an attempt was made in 1953 to restore the soil microflora before reinoculation by watering on a soil suspension. This, however, had no effect on the growth of *D. lycopersici* as measured by the amount of disease possibly because the inoculum consisted mainly of bacteria.

In the present experiments, a layer of maiden loam was placed on some plots which it was hoped would filter out most of the *Didymella* spores. In other plots a similar amount of maiden loam was pricked into the surface layers. Both these treatments significantly reduced the number of basal lesions. Where the soil was mulched, the number of lesions was reduced to 28 compared with 56 in the control. Where the maiden soil was pricked in, the reduction was less. The number of lesions, 38, was, however, significantly lower than the controls.

Since *D. lycopersici* appears unable to establish itself on unsteamed glasshouse soil, it seems remarkable that it should be able to grow and produce lesions when a mulch of maiden loam was present. It is probable however, that a proportion of the spores were washed through into the sterilized soil beneath. Under natural conditions where spores are airborne it is probable that no infection would have resulted. Various other methods of applying the spores were tested but no practical alternative to watering on a spore suspension was found.

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2. VIRUS DISEASES

R. HOWLES

Tomato seed infected with mild tobacco mosaic virus.

Treatment with hydrochloric acid. The procedure was as carried out by Chamberlain and Fry (1). Seed contents (not pulped whole fruit) were thoroughly mixed and then divided into two equal parts. Acid was added to one half, an equal amount of water to the other. Amounts of virus in and on treated and in and

on untreated seed were compared by the half leaf method. The data obtained are given in Table I. Hydrochloric acid treatment did not clean virus-infected tomato seed.

TABLE I
EFFECT OF HYDROCHLORIC ACID ON AMOUNT OF VIRUS ON AND IN VIRUS-INFECTED TOMATO SEED

Variety of Tomato	Number of Lesions	
	Treated Seed	Control Seed
Potentate	53	76
E.S.I.	25	15
Down's Seedling	37	96
Ailsa Craig	195	233
Potential	174	159

Treatment with 2-chlorophenoxyacetic acid. Potentate seed was separated and mixed. 2 gm. lots were weighed out and given different treatments, 16 ml. of solution being added in each case. The seed was rinsed with water afterwards. Virus contents were compared by the half leaf method in the case of seed treated with the strongest solution for the longest duration and in the case of another treatment ; the effect of the former treatment on the seed itself was determined. Table II contains the data. There was no complete inactivation of virus.

Two gm. of seed were treated with 16 ml. of 0.04% 2-chlorophenoxyacetic acid and another two gm. with 16 ml. of water. In each case the seed was in an open Petri dish. At the commencement of germination the liquids were poured off. The seed treated with acid was rinsed. The two lots of seed germinated approximately at the same time. The effect of the treatment with acid on the seed itself and the effect on virus content are given in Table II. The treatment with acid almost cleaned the seed leaving it unharmed. (a) Confirmatory experiments were carried out. There was no germination in the case of slightly longer treatment (and no virus left). Treatment lasting six days, slightly shorter than in the first experiment, did not harm the seed (b) but left a small amount of virus present. However when the seed was germinated in water there was no virus at commencement of appearance of radical. (A considerable amount of virus disappears during germination, possibly from enzyme action).

TABLE II
EFFECT OF 2-CHLOROPHENOXYACETIC ACID ON VIRUS-INFECTED TOMATO SEED

Treatment	No. of seeds which had germinated out of 45, 17 days after sowing	Appearance of Seedlings	Average weight of Seedlings
0.04% acid for 4 days	40	Normal	0.066 gm.
Control seed	38		0.072 gm.
0.04% acid until seed commencing to germinate	(a) 32	Normal	0.3 gm.
	(b) 39	Normal	0.046 gm.
Control seed (not previously kept moist until commencing to germinate)	(a) 44		0.4 gm.
	(b) 42		0.07 gm.

Treatment	No. of experiments	Mean No. of lesions	
		Treated seed	Control seed
0.04% acid for 4 days	2	218	296
0.02% acid for 2 days	2	154	240
			(Control seed kept moist until commencing to germinate)
0.04% acid until seed commencing to germinate	3	2	11

Lettuce seed infected with lettuce mosaic virus. Treatment with 2-chlorophenoxyacetic acid.

A portion of Cheshunt 5B lettuce seed, virus-infected and mixed, was treated with 0.02% chlorophenoxyacetic acid for two days but the seed was not freed from virus. The effect on the seed itself and on percentage infected plants are given in Table III.

TABLE III
EFFECT OF 2-CHLOROPHENOXYACETIC ACID ON VIRUS INFECTED LETTUCE SEED
Seed treated with 0.02% 2-chlorophenoxyacetic acid for 2 days

	No. of seeds which had germinated out of 45, 17 days after sowing	Appearance of seedlings	Average weight of seedlings
Treated seed	13	Normal	0.047 gm.
Control seed	16		0.052 gm.

Experiment	% mosaic infected plants	
	Treated seed	Control seed
1	2	7
2	20	20
3	14	10

Chrysanthemum cuttings infected with chrysanthemum flower-distorting virus.

Chrysanthemum cuttings infected with chrysanthemum flower-distorting virus were given further treatments with compounds related to 2, 4-dichlorophenoxyacetic acid. A treatment was applied to 20 plants, each receiving 100 ml. of solution per day. The plants were tested for virus one month later. The data obtained are given in Table IV.

2-Chlorophenoxyacetic acid did not produce virus-free plants which resulted from the treatment by the chemical last year. Distorted plants caused by other treatments were found free from virus but when tested later—results in Table IV—few (six) had remained clean.

TABLE IV
EFFECT OF COMPOUNDS RELATED TO 2, 4-DICHLOROPHENOXYACETIC ACID ON CHRYSANTHEMUM CUTTINGS
INFECTED WITH CHRYSANTHEMUM FLOWER-DISTORTING VIRUS

Treatment		No. of applications One application was 100 ml. per plant per day	Effects on plants themselves	No. of infected groups (a) ; infected distorted plants (b); in each case more than one month later. Group consists of five plants
Chemical	Concentration			
2-Chlorophenoxyacetic acid	$\frac{1}{2}$ saturated	1	Plants unharmed	(a) 4 out of 4
Ditto	Ditto	2	Ditto	(a) 2 out of 4
Ditto	Ditto	4	Ditto	(a) 3 out of 4
Ditto	Saturated	2	Ditto	(a) 4 out of 4
Ditto	Ditto	4	Ditto	(a) 4 out of 4
Ditto	Ditto	8	Foliage partially yellow	(a) 4 out of 4
2,4-Dichlorophenoxyacetic acid, ammonium salt	0.013%	2	Distortion, flagging	(a) 4 out of 4 (b) 3 out of 9
4-Chlorophenoxyacetic acid	Saturated	3	Flagging	(a) 4 out of 4 (b) 1 out of 4
3-Chlorophenoxyacetic acid	0.013%	5	Slight distortion	(a) 2 out of 4 (b) 2 out of 12
2-Chlorophenoxyacetic acid	0.013%	1		(a) 4 out of 4

Flower distorting virus disease of chrysanthemums.

Incubation period of floral symptoms of chrysanthemum flower-distorting virus disease.

The attempt to determine the incubation period of floral symptoms of chrysanthemum flower-distorting virus disease was continued. Virus was transmitted to clean Late Delight plants by (a) sap inoculation of heat treated plants and (b) grafting on to them infected scions which were cut off six weeks later. Plants were tested for virus two months after treatment of heat treated plants and six weeks after removal of scions. The data which were obtained are given in Table V.

TABLE V
INCUBATION PERIOD OF FLORAL SYMPTOMS OF CHRYSANTHEMUM FLOWER-DISTORTING VIRUS DISEASE

Date of applying virus to heat treated virus free plants	No. of plants treated	No. of plants which became infected	Date	Description of flower of infected plants
30/3/54	20	1	6/12/54	Plant No. 2 3 blooms. Colour break (florets streaked with pink) Distortion.
1/5/54	28	8		
				20/12/54 Plant No. 4 Slight distortion. Plant No. 5 Colour break. Distortion.
				3/1/55 Plant No. 3. Slight colour break. Distortion.
			24/1/55	Plant No. 8. Colour break (florets streaked with yellow). Distortion.
15/5/53	24	1	3/11/53	Distortion
30/6/54	24	1	30/11/53	Colour break
6/8/54	24	3	6/12/54	Distortion No blooms appeared

Date of grafting virus infected scion on virus free stock	No. of infected stocks	Date	Description of flower Nos. those of infected stocks.
2/4/54	3	22/11/54	No. 1. Colour break (florets streaked with pink). Distortion. No. 2. Colour break
14/4/54	4	29/11/54	No. 3. Colour break. Distortion
		29/11/54	No. 2. Colour break. No. 4. Colour break. Distortion
		20/12/54	No. 1. Distortion. No. 3 Colour break. Slight distortion
25/4/54	3	22/11/54	No. 3. Colour break
		6/12/54	No. 1. Colour break
		28/12/54	No. 2. Distortion
5/5/54	11	22/11/54	No. 1. Distortion. No. 2. Colour break. No. 6. Colour break. No. 10 Colour break
		29/11/54	No. 2. Distortion. No. 4. Distortion. No. 8. Colour break. Distortion
		6/12/54	No. 14. Colour break. Slight distortion
11/6/54	5	13/12/54	No. 4. Distortion
		22/11/54	No. 1. Colour break. Distortion
		29/11/54	No. 3. Colour break. No. 8. Colour break. No. 9. Colour break. No. 10. Colour break
		6/12/54	No. 4. Colour break. Distortion
			No. 6. Colour break
27/7/54	1	28/12/54	No. 3. Colour break
8/10/54		31/1/55	No blooms had appeared

In the case of both methods of transmission, blooms which opened the same season exhibited colour breaking and were distorted. Hence it will be necessary to fumigate the plants regularly at all stages to avoid distorted blooms being produced.

Attempt to reduce the incubation period of symptoms due to chrysanthemum flower-distorting virus in *Nicotiana glutinosa* in winter.

19/7/54. Chrysanthemum flower-distorting virus was applied to four groups of *Nicotiana glutinosa* plants, eighteen per group.

Groups 1 and 2. On each of four days immediately preceding treatment with virus the root system of each plant received respectively 100 ml. of 1% sodium nitrate and of 0.025% zinc sulphate.

Group 3. On each of four days immediately preceding treatment with virus the shoot system of each plant was sprayed with 0.2% ferrous ammonium sulphate. Deposits of this chemical were rinsed off on the day before application of virus (to dry foliage).

Group 4 was the control group. Groups 3 and 5. On each of four days immediately preceding treatment with virus the root system of each plant received 100ml. of water.

30/7/54. The number of plants showing symptoms of infection was :—

Group 1 : 14 Group 2 : 6 Group 3 : 5 Group 4 : 2

1% sodium nitrate applied to the root systems of *N. glutinosa* plants greatly increased their susceptibility to chrysanthemum flower-distorting virus *i.e.* made them more sensitive test plants.

An inconclusive experiment in which sodium nitrate was applied to one group of plants was carried out during the winter.

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3. NITRIFICATION IN STEAM-STERILIZED SOIL

By Dr. R. KLEIN

The effect of steam sterilization on the nitrogenous compounds of the soil and the re-establishment of the nitrogen balance during the time between sterilization and planting-out of the tomato seedlings has been examined by chemists but microbiologists tried only to isolate the organisms responsible for the nitrification without investigating the process in the soil and its relation to physical and chemical changes in the substrate caused by sterilization, digging, fertilizing and planting.

It was clear from the outset that a research programme dealing with the microbiological part of the nitrification in soil was a long-term affair and could be dealt with only step by step, as follows :—

- (a) The isolation in crude cultures of the nitrifying bacteria occurring in glasshouse soil (tomato houses),
- (b) The separation of *Nitrosomonas* and *Nitrobacter*, and the study of their physiology in mixed cultures containing other organisms which are considered as contaminants but might be necessary as symbionts to maintain the activity of the nitrifiers,
- (c) The purification and cultivation in pure cultures and the maintenance of mixed and pure cultures,
- (d) Improvement of cultural conditions for mixed and pure cultures with the object of large-scale production,
- (e) The effect of certain chemicals such as antibiotics, insecticides and fungicides,
- (f) Other problems that might occur during the course of this laboratory work.

Only when these problems have been satisfactorily answered can one start to investigate the part the nitrifiers play in the soil, how their activity is affected by steam sterilization and whether nitrification can be regulated in accordance with the needs of the plants by mass inoculation with laboratory-produced cultures and/or addition of certain other substances to the soil.

A further point of this research programme was the investigation of the nitrification in cucumber houses where conditions are quite different owing to the stagnation and lack of aeration in the soil.

Although it was intended to isolate the nitrifiers from glasshouse soil in Cheshunt, it was also thought advisable to compare these organisms with isolates produced by other workers. It was not possible, however, to obtain pure cultures from sources in this country or abroad. The number of microbiologists working with nitrifying bacteria is very small since the difficulties in this field of research and the time involved make

it apparently unattractive, for most workers who start upon this work usually give it up after a few years and do not maintain their cultures ; nor does the National Type Culture Institute keep cultures of these organisms. The only culture which could be obtained from abroad was one of *Nitrosomonas* which proved very weak and contained also *Nitrobacter*. The work had, therefore, to be limited to isolates from the glasshouse soil from Cheshunt and Littlehampton.

The experiments were started in February, 1953, with soil from Tomato House No. 1 in Cheshunt. This soil was supplied by Dr. Davies in a 250 ml. Erlenmeyer flask containing ca. 100 grm. to which he had added 10 ml. of $\text{NH}_4\text{H}_2\text{PO}_4$ (300 p.p.m.N). The flask had been incubated at 23.5°C for three days. The culture media used were prepared after the formulas given by Fred and Waksman (1) : Medium 48 (p. 22) for *Nitrosomonas*, Medium 51 (p. 23) for *Nitrobacter*. The test reagents were prepared according to the same source : Nessler's Reagent (p. 56) for ammonia, Trommsdorf's Reagent (p. 57) for nitrite and Diphenylamine Reagent (p. 59) for nitrate. Occasionally, Griess-Ilosvay Reagent, prepared after a formula used in the Chemistry Department, was also used in the tests for nitrite.

The glassware used was, with a few exceptions, always of the same brand, viz. "Hysil". As the available incubator space was not sufficient to allow the setting-up of all the cultures in Erlenmeyer flasks it was necessary to use also test tubes with 5 ml. of medium and 1" boiling-tubes with 10 ml. of medium. Since nitrifiers develop best in shallow layers of liquid media with great surface, the tubes were kept in wire baskets in sloped position to decrease the depth and widen the surface of the media. The Erlenmeyer flask cultures and boiling-tube cultures were duplicated, the test tube cultures quadruplicated, and half of their numbers were tested on alternate days. The incubator was first kept at 26-28°C. Later when space was found in a second incubator at 25°C, the temperature was increased to 30°C which is probably optimal or near-optimal for nitrifiers. When experiments were repeated the cultures were sometimes put into the incubator with the different temperature to see whether the difference of 5°C had much effect on the cultures. It seems that for practical purposes there is not much to choose within the tested range but this might be different when optimal concentrations of the culture media and of chemicals have to be determined.

For the preparation of the first cultures, the crude cultures, 0.1 grm. of soil was added to each of two 250 ml. Erlenmeyer flasks containing 25 ml. of Medium 48 and to each of two such flasks with Medium 51. Another series with 4 grm. of soil added to each of four flasks was set up simultaneously since it was not known whether the small amount of soil would contain a sufficient number of nitrifiers to start very active cultures. As it turned out when the *Nitrosomonas* cultures were tested, those with 0.1 grm. of the soil were more suitable for subculturing since the development of *Nitrobacter* was more delayed than in those with 4 grm. of soil thus giving a better chance to separate *Nitrosomonas*, whereas in Medium 51 the difference was less pronounced. One of the latter flasks with 0.1 grm. of soil showed the disappearance of nitrite and the appearance of nitrate slightly quicker than the other flasks and was used for subculturing.

This was carried out at various intervals, differing from about one week to three weeks. In the beginning it was, of course, possible to make the transfers at short intervals but when the number of cultures increased as the experiments branched more and more and several questions had to be investigated in parallel experiments to allow the use of cultures of the same generation and the same age, it was necessary to extend the transfer intervals. Sometimes cultures had to be kept for a longer period to examine the effect of additional substances and new series with modifications were set up in the meantime. However, as the making of transfers, testing and the preparation of media and reagents was done single-handed, it was not always easy to work out a time table in which all these phases would overlap in such a way that the critical dates for testing of the cultures—the first appearance of nitrite and nitrate, respectively, and the maximum reactions—should not be missed.

The cultures soon showed marked differences in speed and intensity of nitritation and nitrataion, respectively, in a way which indicated that the original cultures had split into various strains. Three of each of these *Nitrosomonas* and *Nitrobacter* strains were selected to be used for continuous subcultures and various experiments. Up to the end of 1954 altogether 24 transfer series were made of each of the three *Nitrosomonas* and *Nitrobacter* cultures. From time to time the cultures were tested for their sterility and although it could be clearly seen, without making bacterial counts, that the number of contaminants decreased in the course of the transfers and a partial purification of the cultures gradually took place, it seems more than doubtful that pure cultures of nitrifiers can be obtained by continuous subculturing in liquid media. Reports of workers that they were successful in obtaining pure cultures in this way as, e.g., stated by Rao and Pandalai (2), will always be met with doubts that their claims cannot be substantiated. There are some accompanying organisms present, whether they be contaminants or symbionts, from which the nitrifiers apparently cannot be separated by this technique. T. Y. Kingma Boltjes (3) and H. Bömeke (4) have investigated this question more thoroughly than others did, and found that it is not only necessary to work with utmost care

but also to be highly critical in making sterility tests as not to be misled into the belief that one is working with pure cultures when in fact other organisms are still there. The media usually used for sterility tests are nutrient broth, nutrient agar and glucose-asparagine agar but since *Hyphomicrobium* does not grow on these media it is necessary to add another sterility test by using yeast water (Bömeke, 1.c) and even there growth starts only after a long incubation period and is very scanty.

It is generally assumed that pure cultures of nitrifiers can only be obtained by cultivation on silica gel or washed agar plates where the complete absence of organic substances prevents the growth of nearly all the other micro-organisms. This method is one of the most tedious owing to the difficulties in preparing these plates and the slow development of the nitrifiers although they are there freed of the competition of most of the other bacteria, especially on silica gel plates. It was, therefore, thought advisable to try other ways which were not known at the time when Winogradski and other microbiologists worked in this field, and the use of tetrazolium chloride or of antibiotics to eliminate contaminants was considered worth trying. Some preliminary experiments led to the choice of clavatin* and, whilst the work of continuous transfers was carried on at the same time, a number of experiments was set up in which this drug was added in varying quantities. Both *Nitrosomonas* and *Nitrobacter* were more or less inhibited under the conditions of the experiments but *Nitrosomonas* proved far more resistant and survived in cultures in which most of the contaminants could be eliminated. Two cultures seemed more promising than all the others and were kept over a long period for testing and enrichment. When they were subcultured in the end, sterility tests showed that they were more contaminated than before which was either due to the unfavourable working conditions—the cultures had to be opened repeatedly for testing of their activity—or to the development of clavatin-resistant strains. The experiments had at this point to be interrupted to allow the setting-up of others which were considered at that stage as more important. Among them was, of course, the attempt to obtain pure cultures by using silica gel plates.

As already mentioned, the preparation of silica gel plates is not simple and the usual methods of dialysing the silica gel or using a base-exchange column are laborious. If the silica gel is prepared in Petri dishes by using hydrochloric acid, the plates have to be washed for a long period under running water which is no guarantee for the removal of undesirable substances. It was found that the method used by Duché and Neu (5 and 6) who avoided these troubles by using H_3PO_4 instead of HCl after they had dissolved the nutrient substances in the phosphoric acid, could be adapted successfully for the cultivation of nitrifiers. In making plates with Media 48 and 51 the method had to be considerably modified but worked well, saving time and labour. The plates could be inoculated with a loop made from a 38G platinum wire which did not cut into the surface and, therefore, prevented liquid from oozing out. As hardly anything could be seen on the plates for some time, it was advisable to draw lines with a chinagraph pencil on the bottom part of the plates and inoculate along these lines. The plates were then sealed with cellulose tape and incubated upside down. The colonies developed very slowly and were almost minute. As it was not possible to work with *Nitrosomonas* and *Nitrobacter* simultaneously besides having other experiments on hand, only a few plates were made of the latter to find out whether the method might in principle be workable and then this part of the work was concentrated on *Nitrosomonas* with the result that a pure culture was obtained as a subculture from one of the colonies. This subculture had been incubated at 25°C. for three weeks and then test tubes with the four above-mentioned sterility media were inoculated before the first nitrite tests were made. All the sterility media were still clear after 16 days. In the meantime, the culture was repeatedly tested for ammonia and nitrite and since after that time its activity was still rather low and yet there was hardly any ammonia left, it was decided to add some ammonium borate solution. Before this was done another series of sterility media was inoculated. Whereas the first set stayed clear, the second one showed that the culture had in the meantime become contaminated. This was not surprising considering the conditions under which the work had to be carried out. Owing to the lack of laboratory space, it was done in the room where the media for the Mycological Department were prepared, where soil from the glasshouses was brought in and sterilized for experiments, and which served as a passage between the laboratories and the glasshouses. The work with silica gel plates was, therefore, discontinued in the hope that it would be possible to restart it in a new laboratory at Littlehampton under proper working conditions and, if possible, in an air conditioned inoculation room.

In previous experiments it was tried to improve the culture media by replacing in Medium 48 the ammonium sulphate by succinate and borate, respectively, and by adding to Media 51 succinic acid and sodium borate, respectively. The results of the experiments with succinate and succinic acid were less promising than those with boron and were, therefore, not continued. The experiments with boron were satisfactory, and, therefore, followed up. The results were reported in a short paper (7).

*I should like to express my thanks to MESSRS. ROCHE PRODUCTS LTD., Welwyn Garden City, for the supply of clavatin.

Another possibility of speeding up the rate of development of the nitrifiers, at least *Nitrosomonas*, seems to be the use of shake cultures. The shaking had to be done by hand, several times a day, since there was no means for shaking at constant temperature. The shaken *Nitrosomonas* cultures showed in spite of this primitive treatment a more rapid development. For mass production stirred and aerated vessels as used in fermentation processes might be even more suitable, perhaps also in combination with improved media.

It was intended to examine at a later stage of this work the effect of certain substances such as fertilizers, insecticides and fungicides, on the nitrification in mixed and pure cultures and in the soil, and to find means to counteract their probably damaging effect. During literary preparations for this part of the work it was found that Smith and Wenzel (8) had obtained interesting results when they added cottonseed meal to soil which was treated with insecticides. So cottonseed meal was used as part or complete nitrogen source in laboratory experiments. The effect on the nitrifiers in these preliminary experiments was not conclusive but sufficiently interesting to encourage further experiments with the object of determining the optimum conditions for the action of cottonseed meal in laboratory cultures and then in soil, and afterwards with the addition of insecticides, etc. For the preliminary experiments mixed cultures were used which were isolated from various soil samples taken from the new station.

Since the maintenance of the mixed and pure cultures is of great importance, it is necessary to discover how they can best be kept over a long period without loss of activity and reproductive power. From January to April, 1954, a number of test tube cultures were put under paraffin oil employing the technique used for the maintenance of fungi, and stored in a cupboard for several months. After that time, subcultures were made at different intervals. The experiments showed that this method can be used but it will be necessary to find out the most suitable medium, temperature and other conditions to obtain the best results.

It should be pointed out that owing to the working conditions and lack of help all the experiments described above were set up as preliminary ones without attempts to determine the optimal conditions. It was intended to do this at the new station and also to combine the various culture modifications which were found to be successful.

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III. ENTOMOLOGICAL INVESTIGATIONS

I. RED SPIDER-MITE (*Tetranychus telarius* (L) Koch)

Ey W. J. PARR, C. CROCKER and E. R. SPEYER

1. Effect of starvation upon reproductive capacity

During July, eight female mites in the deuteronymphal resting stage were placed one each upon discs cut from tomato leaflets, and floated on water. They were kept at room temperature under conditions of low light intensity. After each had performed the ecdysis to maturity, the life-span of the adult mites and the number of the eggs deposited by each was recorded. The mites were transferred to freshly-cut leaf discs at intervals of from three to six days.

Two mites lived respectively for 27 and 29 days without depositing any eggs : three were still alive after 28 days, during which they laid respectively 13, 16 and 43 eggs. The life-span of the remaining three mites was respectively 14, 16 and 19 days, and they deposited respectively 5, 11 and 38 eggs. The average number of eggs deposited by these mites, excluding the two which laid no eggs, was 21.

Three female mites obtained in similar manner from the deuteronymph resting stage were transferred, after they had deposited a smaller or larger number of eggs upon the leaf-discs, to cork discs floating on water, and thus deprived of food.

One mite, kept upon a leaf-disc for three days during which it laid four eggs, survived for a period of 10 days upon the cork disc, and another kept upon a leaf-disc for six days, during which it deposited two eggs, lived for a similar period of time after transference to the cork disc. Neither of these mites deposited any eggs upon the cork discs. The third mite, kept upon a series of four leaf-discs over a period of 17 days, during which it laid 39 eggs, survived for 12 days upon the cork disc, over which it spun a large amount of webbing : the mite deposited only one egg upon the cork disc soon after transference to it.

A female mite in the deuteronymph resting stage was placed upon a floating cork disc : after ecdysis to maturity, the mite lived for 9 days upon the disc, over which it spun webbing : it deposited no eggs.

These observations confirm conclusions drawn previously (Rep. Exp. Sta. Cheshunt, 1953, p.32) that deprived of food, the mite forthwith becomes incapable of producing eggs. The food reserves present in the internal organs of the deuteronymph resting stage are sufficient to keep the mite in a living and more or less active state for a period of some 10 days, after it has attained maturity.

A more extensive investigation, under controlled conditions, into factors influencing the reproductive capacity of female mites, is being carried out.

2. Digestive and excretory processes

By confining individual mites upon small discs cut from leaves and floated on water, and observing them over considerable periods of time with the aid of a low-power binocular microscope, it has been possible to throw some light upon the manner in which processes of digestion and excretion are effected.

Considerable portions of the main digestive organ or "ventriculus" and of the hind-gut, which functions as the excretory organ, and especially their contents, were visible through the transparent cuticle. The lumen of the anterior and medium lobes of the ventriculus was filled with dark spherical bodies from 17μ to 35μ in diameter : from the anterior lobe these balls were, on occasions, seen to pass one after another through the extremely narrow canal, which forms a connection between the two organs, into the lumen of the hind-gut.

Sometimes small numbers of these balls were passed into the rectum and voided forthwith through the anus, but usually they accumulated in the lumen of the hind-gut and were eventually voided in a drop of liquid which dried rapidly, leaving a large hard spherical black pellet. If submerged in a drop of water, these pellets could be broken up into their constituents : they were found to contain up to 50 balls, some granular material, and sometimes considerable numbers of droplets of an oily nature.

The balls appear to be single cells and, as contained in the ventriculus, have been referred to by authors as digestive "cells" or "food-balls." Neither of these terms appears to be appropriate, since it is evident that their function is merely to collect products of digestion of the all but liquid plant juices which are

passed through the oesophagus into the ventriculus while the mite is feeding. They accumulate within themselves these products or "faecal" matter, and when saturated with it are passed into the hind-gut and finally voided. The term "faecal balls" is therefore suggested. The quite independent appearance of true excretory matter in the hind-gut has been observed : this was secreted into the lumen by the cells forming the ventro-lateral walls in the interior portion of the organ, and became solidified to opaque white bodies up to 35μ in length and 15μ in diameter. These "uratic spheres" were pushed to the posterior portion of the hind-gut on entry of faecal balls into it, but in absence of the latter, they increased in size and number until the whole lumen of the organ was filled by them.

When voided separately from faecal balls, the uratic spheres were expelled from the anus enveloped in a large drop of liquid which dried rapidly to form a hard white pellet : as in the case of the faecal pellets, they were easily broken up in water into their constituent spheres.

When voided together with them, the uratic spheres showed up clearly upon the surface of the faecal pellets, from which they were readily separable.

By collecting the excreta deposited upon the floating leaf-discs and separating them into their constituent parts, it became possible to count, with considerable degree of accuracy, the actual numbers of faecal balls and uratic spheres which were voided by mites over long periods of time, and by direct observations over shorter ones, to obtain some estimate of the rate at which faecal balls passed from the ventriculus into the hind-gut.

The five adult female mites (designated a – e) kept under observation were collected from tomato plants during September ; their age from the time at which they had reached maturity was not known.

(a) The mite, the hind-gut of which contained a large quantity of matter, was first kept under observation upon a tomato leaflet floated on water. After five minutes it voided the whole contents, comprising 14 faecal balls and four uratic spheres, together with 27 oil globules. Upon the following day it was transferred to a leaf-disc, and during the course of some $4\frac{1}{2}$ hours, five faecal balls passed from the ventriculus into the hind-gut : of these, four were seen to make the passage within a period of five minutes.

During the eight days over which the mite was kept upon the leaf-disc, it voided 101 faecal balls and 15 uratic spheres, and deposited eight eggs. At the end of this period it was of shrunken appearance.

(b) The mite was of a yellowish colour ; the ventriculus contained a large number of faecal balls, many being present at the posterior end of the posterior lobes. The hind-gut contained five uratic spheres, but no faecal balls.

Soon after transference to a leaf-disc, it was seen to be feeding and to deposit an egg. By the following morning, the mite had voided 16 faecal balls and six uratic spheres and laid two more eggs : six faecal balls were seen to pass from the ventriculus into the hind-gut in the course of five minutes.

After 12 days upon the leaf-discs, the mite was active and had voided in all 198 faecal balls and 31 uratic spheres, and had deposited 23 eggs.

(c) The mite was of a greenish colour when transferred to a leaf-disc : the hind-gut contained eight uratic spheres but no faecal balls. After 40 minutes, four faecal balls had passed from the ventriculus into the hind-gut, and these were voided with the uratic spheres in the course of the following 45 minutes.

After 12 days, the mite was alive and active, had voided 161 faecal balls and 40 uratic spheres, and deposited 35 eggs.

(d) The mite, the ventriculus of which contained many faecal balls and the hind-gut two or three small uratic spheres was kept upon a floating cork disc, and thus deprived of food. On the following day, 12 faecal balls passed into the hind-gut during the course of $3\frac{1}{2}$ hours. Only some four of these were subsequently voided with the uratic spheres. The mite was alive but inactive after six days and, deposited no eggs.

(e) The mite, the hind-gut of which contained no faecal balls, was kept upon a floating cork disc. During the six days over which the mite remained alive, few faecal balls passed into the hind-gut, though many were present in the ventriculus when the mite died. The faecal balls were not voided from the hind-gut and no eggs were laid.

3. Rate of development at constant temperatures

During May, an equal number of male and newly-moulted female mites were collected from tomato plants in a glasshouse. One pair of mites was placed each upon a disc cut from a tomato leaflet and floated on water : the pairs were transferred daily to freshly cut discs, and the discs upon which eggs had been

deposited during each successive period of 24 hours were placed, some in an incubator at 66°F constant and others in one at 72°F constant. The discs were examined frequently in order to determine as accurately as possible the period of incubation at each of these temperatures.

The results obtained are shown in Table I, and from them it is apparent that the increase of 6°F had accelerated the average rate of development within the egg by approximately 33%. The difference in viability of the eggs at the two temperatures is not significant.

TABLE I
TETRANYCHUS TELARIUS
PERIOD IN DAYS OF INCUBATION AT CONSTANT TEMPERATURES

EGGS	AT 66°F	AT 72°F
Dates laid	17 - 24. V	11 - 17. V
Dates hatched	26 - 31. V	16 - 22. V
Number laid	51	50
Number hatched	36	43
% viability	71	86
Incubation Period		
Mean	7.6	5.1
Range	6.7 - 9.3	4.5 - 6.0

The red ocellar pigment of the larva developing within the egg-shell made its appearance at the lower temperature upon the 6th day, and at the higher one round about the 4th day after the egg had been deposited. At these respective periods, the eggs, which at deposition were pearly white, had assumed a light brown colour.

Some of the larvae obtained were kept upon floating tomato leaf-discs in the incubators in which the eggs had hatched. Each larva was kept upon a separate disc and transferred to a fresh one periodically during its development.

The mortality of the larvae in the 1st instar was very high. Of 24 larvae in the incubator at 66°F 12 (2 males and 10 females), and of 32 larvae in the one at 72°F 13 (1 male and 12 females) completed their development to maturity.

From the records obtained and summarised in Table II, it became apparent that the rise of 6°F in temperature had caused an average acceleration of approximately 40% in the development of the female mites. At both lower and higher temperatures the range of variation in the duration of development for individual females was remarkable, and possibly due to differences in the amount or quality of the nourishment obtainable by them from the leaf-discs. The number of males which developed to maturity was too

TABLE II
TETRANYCHUS TELARIUS
RATE OF DEVELOPMENT AT CONSTANT TEMPERATURES

Instar		PERIOD OF DEVELOPMENT IN DAYS						
		At 66°F				At 72°F		
		10 Females		2 Males		12 Females		1 Male
		Mean	Range	Mean	Range	Mean	Range	
Larva	active	3.3	2.8 - 4.5	4.7	3.8 - 5.5	2.0	1.5 - 3.0	3.5
	quiescent	1.6	1.0 - 2.0	1.7	1.5 - 2.0	0.9	0.6 - 1.0	1.0
Protonymph	active	2.7	1.5 - 4.5	1.7	1.5 - 2.0	2.0	1.0 - 4.0	4.0
	quiescent	2.1	1.5 - 3.0	1.7	1.5 - 2.0	1.1	0.5 - 1.8	1.0
Deuteronymph	active	3.5	2.5 - 5.3	1.9	1.7 - 2.0	1.9	1.0 - 3.0	1.5
	quiescent	2.4	2.0 - 2.8	2.0	—	1.4	1.0 - 2.0	0.5
TOTAL		15.6	12.8 - 17.3	13.7	—	9.3	6.9 - 11.4	11.5

small to enable comparisons to be made, and the one larva kept at 72°F spent a quite abnormally long period of time in the active phase of the protonymphal instar.

Taking, however, the average for all the mites from which the records were obtained, there was an acceleration in the overall development from deposition of the egg to attainment of adult maturity of approximately 38%.

4. Effects of air-circulation upon rate of reproduction

In his description of 1758, Linnaeus stated that the mite to which he gave the specific name "*telarius*" occurred upon plants growing in situations little exposed to winds, and "suffocated plants grown in hot-houses by covering them with webbing."

An attempt was therefore made to determine whether or not increase of the mite was less rapid upon tomato plants growing in a glasshouse in which the atmosphere was kept in continuous circulation by means of an electric fan than upon similar plants in one of which the atmosphere was, to all intents and purposes, stagnant.

In a small glasshouse divided by a transverse partition into two sections one of 1000 and the other of 2000 cubic feet capacity, staging was erected upon the same side in each partition. In the smaller one, an electric fan was installed, fixed at ground level in the centre of the path at one end, and tilted at an angle so that the blast of air was directed towards the ridge at the other end.

Onto the foliage of 48 tomato plants (var. E.S. 1) with an average height of 7 inches and with 6-7 leaves expanded, growing in "60" size pots, two female mites which had attained maturity and been fertilized by males not more than two days previously, were introduced.

Two days later—on June 25th—markings upon the leaflets showed that the mites had started feeding : 24 plants were arranged in four rows equidistant from one another upon the staging in each partition. The electric fan was then started and kept running continuously day and night.

Attempts made to record the velocity of the air current in the vicinity of each plant with the aid of a vane anemometer were unsuccessful as a result of irregularity in the readings obtained for each position. Temperatures in each partition were recorded throughout the experiment.

Six days after the fan had been started, all the plants were repotted in "32" size pots.

Subsequently three plants in each partition developed severe symptoms of virus disease and were discarded.

The foliage of the three plants in the row adjacent to the fan was kept in a violent state of agitation, and after 17 days the leaflets of one or two leaves on two of them showed distortion, had dessicated areas upon their surfaces, and had become brown round their edges.

On July 29th, when the experiment had been in progress for five weeks, the plants in both partitions had attained a height of 3-ft.. The degree of infestation upon each of them was assessed by taking a count of the number of whole leaves which showed feeding marks made by the mites, and expressing this number as a fraction of the total number of leaves upon the plant : the extent of the feeding marks was also used to supplement the assessment.

In both partitions, the total number of leaves upon each plant ranged from 17 to 20 : in the one in which the atmosphere was stagnant the number of leaves infested by the mites ranged from 10 to 17, and in that in which the air was circulated from 7 to 13.

In the partition in which the atmosphere was stagnant 262 out of a total of 381 leaves were infested, a percentage of 69 : the degree of infestation was moderate upon 13, slight to moderate on five, and slight upon three plants. The temperatures recorded were mean 73.8°F, maximum 100°F and minimum 52°F.

In the partition in which the air was circulated, 231 out of a total of 392 leaves were infested, a percentage of 59 : the degree of infestation was slight to moderate upon eight, slight on 10 and very slight on three plants. Upon three plants the foliage of which had been kept in a violent state of agitation as a result of their proximity to the fan, a total of eight leaves had been injured in the manner described above : 35 leaves out of a total of 59 were infested, the degree of infestation being slight to moderate upon two plants and slight upon the third. The temperatures recorded were mean 69.4°F, maximum 90°F and minimum 55°F.

From these data it appeared that the mites had reproduced themselves rather less rapidly upon the plants growing in an atmosphere which was kept constantly in a state of circulation. This was probably due more to a lowering of the mean temperature by some 4°F than to any direct effect of air currents upon the mite.

2. GREENHOUSE WHITE-FLY (*Trialeurodes vaporariorum* Westw)

By C. CROCKER

Experiments with Parathion and allied Compounds

A commercial sample of Parathion, in dispersible form, from which impurities had not been removed was diluted to give concentrations respectively of one part in 50,000, and one part in 100,000 parts water.

The soil contained in pots in each of which a young *Nicotiana Tabacum* plant was growing, was watered with the diluted sample, 4 pots receiving the higher and 4 pots the lower concentration : 4 pots containing similar plants growing in untreated soil served as controls. Upon the day of application and again after intervals respectively of 15, 21 and 29 days, the plant in one pot which had received the higher, in one which had been watered with the lower concentration, and in one control pot were each covered with a lampglass with its lower end resting upon black blotting paper which covered the soil surface ; the upper end was covered with gauze to prevent escape of the insects.

In each lampglass approximately 200 adult white-flies of unknown age were liberated, and daily counts were subsequently made of the living and dead insects. Details of the numbers surviving daily for each batch of flies introduced at given intervals of time over the whole period of 34 days after the application of the Parathion sample to the soil are given in Table III.

TABLE III

Days after application	Numbers White-flies alive		
	Conc. Parathion sample in water		Untreated control
	1 in 50,000	1 in 100,000	
0	200	200	200
1	199	200	200
2	171	149	199
3	0	0	199
15	200	200	200
16	198	198	199
17	196	195	199
19	0	6	197
20	—	0	197
21	200	200	200
22	200	200	198
23	194	198	192
24	80	130	184
26	0	38	160
27	—	38	160
29	200	200	200
30	197	195	198
34	194	186	182

The results may be summarised as follows :

- (a) White-flies introduced upon day of application.

With both concentrations all were dead within 3 days : the majority succumbed between the 2nd and 3rd days. In the control, only one was dead upon the 3rd day.

- (b) White-flies introduced 15 days after application.

With the higher concentration, all were dead within 4 days, and with the lower, only 6 were alive upon the 4th day : the majority succumbed between the 2nd and 4th days after introduction. In the control, 3 died during this period.

- (c) White-flies introduced 21 days after application.

With the higher concentration, the flies died off rapidly after the 2nd day and none remained alive on the 5th day after being introduced. With the lower concentration, 68 died between the 2nd and 3rd days, and 92 between the 3rd and 5th days after introduction.

In the control, 8 died between the 2nd and 3rd and 24 between the 3rd and 5th days after introduction.

- (d) White-flies introduced 29 days after application.

With both concentrations, only a small number died during the succeeding 5 days ; the mortality was, in fact, lower than that obtaining in the control over the same period.

It was observed that within the lampglass covering the plants in the treated soil there were many more flies settled upon the inside of the glass, and consequently far fewer upon the foliage, than in the glass covering the control plants. In the case of the flies introduced 21 days after application, 15 to 30 per cent. of those surviving upon the 3rd day were counted upon the glass covering the two plants in the treated soil, whereas all the flies in the control had at that time moved onto the foliage. This suggests that the foliage of the plants in the treated pots had been rendered distasteful to the flies, and that they only returned to it when hunger forced them to do so.

It was concluded from the results of this experiment that some substance present in the crude sample of Parathion, at both concentrations at which it was used, possessed the properties of a systemic insecticide, which was taken up by the roots and rapidly distributed to the foliage in which it persisted in quantity sufficient to cause the death of white-flies for a period of at least 21 days after it had been applied to the soil. There was some evidence to indicate that the lethal properties tended to disappear from the foliage after a period of 25 days, when applied at the lower, and after some 29 days at the higher concentration.

Experiments of a similar nature were later carried out with pure Parathion and with its s-ethyl isomer, dispersed at the rate of one part in 22,500 parts water, and applied to the soil of pots in which tomato plants were growing. Neither of these compounds acted upon the white-flies as a systemic insecticide.

With "E.600"-Paroxon (a derivative of Parathion soluble to the extent of one part in 1000 parts of water) applied to the soil in similar manner, 28 white-flies given access to the foliage of a tomato plant succumbed within 3 days : of 31 flies confined upon the control plant, only 4 died during this period. It therefore became highly probable that the compound which acted as a systemic insecticide in the crude sample of Parathion used in the first experiment was "E.600."

IV. INSECTICIDES AND FUNGICIDES

I. FUNGICIDES

By W. H. READ, J. T. HUGHES and R. J. SMITH

Laboratory Investigations

The *in-vitro* fungitoxic activities, against spores of *Fusarium culmorum*, of certain derivatives* of quinoxaline obtained from the Atomic Energy Research Establishment, Harwell, have been investigated by the test-tube dilution method.

The compounds tested, together with the percentage inhibitions of germination of the spores at the concentrations tested, are listed below. For testing, these compounds were finely ground and in addition to the test compound, the final test suspension contained 0.002% Cellofas A. The spore concentration employed was *c.* 125,000 spores per ml.

TABLE I

Compound	Concentration tested (%)	% inhibition of spore germination
2-(2-Hydroxyphenyl)-quinoxaline	0.10	2
	0.05	0
	0.02	0
	0.01	0
2 : 3-Dimethyl-5 : 8-dihydroxyquinoxaline	0.10	100
	0.05	99
	0.025	95
	0.01	63
	0.003	26
2 : 3-Diphenyl-5 : 8-dihydroxyquinoxaline	0.10	59
	0.05	23
	0.025	12
	0.01	3
	0.003	0
2 : 3-Diphenyl-5-hydroxyquinoxaline	0.10	0
	0.05	2
	0.025	0
	0.005	0
2 : 3-Di(a-pyridyl)-5 : 8-dihydroxyquinoxaline	0.10	81
	0.05	47
	0.025	50
	0.01	26
	0.003	9
1 : 4-Dihydroxy-5 : 6 : 9 : 10-phenanthraphenazine	0.10	15
	0.05	4
	0.025	2
	0.01	0

It is apparent that, of the above compounds, only those possessing a hydroquinoid system have fungitoxic properties (at least against spores of *F. culmorum*).

GLASSHOUSE TRIALS

Tomato leaf-mould

Salicylanilide has, for many years, been used for the control of certain fungus diseases, including tomato leaf-mould (*Cladosporium fulvum* Cke.), and although frequent application of 0.06% salicylanilide

*Acknowledgement

We wish to thank Mr. E. S. Lane and Mr. C. Williams of A.E.R.E., Harwell, who prepared these compounds.

may be necessary to effectively control this disease, salicylanilide is, in general, a very safe fungicide which does not cause appreciable marking of the fruit by deposits. A recent development has been the application of salicylanilide to tomatoes by "low-volume" spraying and satisfactory control of tomato leaf-mould is stated to be obtained by this method.

There are, apparently, no records in the literature of trials with chlorinated salicylanilides against plant diseases and, in view of the possibility that such compounds might possess the ability to more readily penetrate the leaf tissues and thus be more advantageously applied by low-volume methods, a number of these compounds, namely the anilides, 4-chloroanilides, and 2 : 4-dichloroanilides of salicylic acid and 3 : 5-dichlorosalicylic acid were, where necessary, synthesised and tested against tomato leaf-mould in sprays containing 0.025% Cellofas A, as a dispersing and wetting agent.

In each comparison, the 3 : 5-dichlorosalicyl-derivative was rather more active, at the same molar concentration, than the corresponding salicyl-derivative.

The investigation is being continued and a full report will be published elsewhere.

In addition, the eradicant activities, against tomato leaf-mould, of the above-mentioned derivatives of quinoxaline, have been determined at the concentrations stated in Table 2.

TABLE II

Compound	Concentration
2-(2-Hydroxyphenyl)-quinoxaline	0.40%
2 : 3-Dimethyl-5 : 8-dihydroxyquinoxaline	0.40%
2 : 3-Diphenyl-5-hydroxyquinoxaline ...	0.55%
2 : 3-Diphenyl-5 : 8-dihydroxyquinoxaline	0.55%
2 : 3-Di(a-pyridyl)-5 : 8-dihydroxyquinoxaline	0.55%
1 : 4-Dihydroxy-5 : 6 : 9 : 10-phenanthraphenazine	0.55%

When these compounds were tested in sprays containing 0.025% of Cellofas A as dispersing and wetting agent only 2 : 3-dimethyl-5 : 8-dihydroxyquinoxaline showed any obvious effect against the fungus. However, only the older lesions were appreciably affected by this compound, an effect which is probably connected with the marked damage to the leaf tissues containing, and immediately surrounding, the fungus. The young, less well-established mould was unaffected.

On non-infected leaf tissue none of the compounds tested were phytotoxic at the concentrations used.

Trials with fungicides, for the control of tomato leaf-mould showed that captan (N-trichloromethyl-thio-cyclohex-4-ene-1 : 2-dicarboximide at 0.1% in combination with a wetting agent was ineffective.

Tests made with a sample of manganese dimethyldithiocarbamate yielded variable results which may have been due to the instability of this compound. In early trials the manganese dimethyldithiocarbamate at 0.2% active material, in combination with a wetting agent, gave results equal to those given by a standard copper oxychloride-petroleum emulsion spray and caused only slight soiling of the fruit.

In later trials with the product, at 0.2% active material, the effect on fungal growth was considerably less than in the earlier trials.

Increased fungicidal action was obtained from copper dimethyldithiocarbamate (0.2%) - petroleum emulsion (0.7%) sprays but such mixtures proved phytotoxic to tomatoes and cucumbers even when the thiocarbamate content was reduced to 0.05%. In this connection it is of interest to report that cases of damage to glasshouse crops following the use of thiram-petroleum mixtures have been investigated and the incompatibility of thiram preparations with petroleum emulsion sprays has been established.

Cucumber mildew

Additional trials show have that 4 : 6-dinitro-2-secoctylphenyl crotonate, in the form of a proprietary wettable powder stated to contain 25% of the technical compound, gives very good control of cucumber mildew at 0.01% active material. Where plants were badly attacked before control measures were commenced it was found advantageous to give two spray applications at an interval of 10-12 days. Only one application was required to control the disease on plants which showed only young, small patches of mildew and where conditions were unfavourable to further infection.

Tetrachloronitrobenzene (tecnazene), when dispersed as a smoke, did not give a satisfactory control of cucumber mildew when used in amounts which caused damage to well-established cucumber plants.

Didymella stem rot

The search for effective eradicant fungicides for the treatment of *Didymella lycopersici* Kreb on tomato stems was continued, using the method of testing outlined in the Annual Report for 1953, namely, the application of the fungicide in a kaolin paste. Two of the compounds, actidione and streptomycin sulphate were, however, applied in a lanolin paste.

None of the compounds caused any obvious injury to the plants at the concentrations tested.

However, the compounds tested, listed below, failed to inhibit the development of *Didymella* lesions.

TABLE III

Compound	Concentration in paste
Salicylic acid	20%
5-Chlorosalicylic acid	25%
3 : 5-Dichlorosalicylic acid	25%
3 : 5-Dichlorosalicylanilide	25%
3 : 5-Dichlorosalicylaldehyde	20%
2-Hydroxybenzylideneaniline	25%
2-Hydroxybenzylidene-4-chloroaniline	25%
4-Acetoxy-2 : 3-dichloro-1-naphthol (m.p. 163°C)	10%
Malachite green	8%
Streptomycin sulphate	0.10%
Actidione (cycloheximide)	0.15%

2. INSECTICIDES

Contamination of Workers' Hands with Parathion

Further experiments to determine the extent of the contamination of workers' hands arising from the cultivation and harvesting of parathion treated tomatoes and cucumbers, have been completed.

Variations in the amounts of parathion residues on leaves in different positions in a glasshouse after a single treatment, and in the amounts resulting from applications of the same treatment under different conditions or in different glasshouses, may be considerable, particularly where the parathion is applied as an aerosol. Because of this and other factors such as the effect of climatic conditions, age of plants and individual characteristics of the workers engaged on cultural practices, many results are needed before the hazards (if any) may be assessed with confidence. Owing to the exigencies of commercial crop production and of other glasshouse experiments proceeding at the same time as these, the total number of results obtained is somewhat limited. However, sufficient information has been obtained to indicate the extent of contamination to be expected under normal practical conditions.

When smokes and aerosols are applied at rates of approximately equal effectiveness in controlling red spider, *e.g.* 0.5g. parathion per 1,000 cu.ft. for smoke generators from which about 25% is discharged unchanged, and 0.5g. per 1,000 cu.ft. discharged unchanged as an aerosol, the deposits on foliage are smaller with the smoke application. Thus, deposits up to 5 p.p.m. were found to result from smoke applications at commercial rates of application and up to 25 p.p.m. from aerosols. Up to 0.01 mg. parathion per hour was found to be picked up on cotton gloves worn when trimming cucumbers treated with smokes at usual rates and up to 0.1 mg/hr. when the same workers trimmed similar plants treated with a parathion aerosol.

It was also found that the trimming of tomato plants treated with either parathion smokes or aerosols resulted in greater contamination of the hands than the trimming of cucumber plants which had received the corresponding parathion application.

Up to 1 mg/hr. was picked up from tomatoes, 16 hours after a standard commercial treatment, as compared with 0.1 mg/hr. from cucumbers. As the differences in the deposits on the foliage were insufficient to account for this, it appears that the difference may be associated with the "pigment glands" on tomato leaves and stems which exude a sticky, pigmented fluid when damaged, leading to greater soiling of the hands.

The residues on the foliage and amounts picked up when handling plants showed a steady decline and in general were reduced to less than 50% and in some cases less than 10%, after four days.

A full description of this work will be given elsewhere.

Distribution Studies

Determinations of deposits of parathion on foliage, made during the course of the above investigation, showed that the insecticide was very unevenly distributed within the glasshouses when applied as an aerosol or a smoke. Indifferent control of certain pests, particularly in low cucumber-type houses, may be due to inadequate distribution of pesticides, and an investigation of the problems was commenced.

Leatherjacket Control

There was a moderate wireworm population and very heavy leatherjacket population in the ground on which the glasshouses were erected at Rustington. The glasshouse borders were treated with a 2% BHC dust at the rate of 2-ozs. per square yard, after digging. The dust was broadcast on to the surface of the soil and well mixed within the upper two inches by mechanical cultivation. No tomato plants grown in these houses showed signs of damage by either pest. The experimental programmes in these houses prevented inclusion of untreated control plots.

V. CHEMICAL INVESTIGATIONS

I. UREA-FORMALDEHYDE COMPOUNDS AS NITROGENOUS FERTILIZERS

By M. I. E. LONG and G. W. WINSOR

The preparation and testing of a range of compounds produced by reaction of urea with formaldehyde under acid conditions has already been described in the Annual Report for 1951¹ and elsewhere². In this way it was possible to prepare urea-formaldehyde products which, when tested under controlled conditions in a market garden soil having a pH of approximately 7.3, showed rates of mineralization of nitrogen similar to that of finely ground hoof and horn. None of the samples tested was considered to fulfil all the requirements of an ideal slow-acting nitrogenous fertilizer, however. In particular it was noted that, as the reaction continued under acid conditions, urea-formaldehyde compounds which were precipitated became increasingly inert when tested in the soil,

Alternative methods of preparation were accordingly examined, in which urea and formaldehyde were first allowed to react in alkaline solution, followed by a brief acid treatment. The general procedure for preparation of the samples was as follows :

Urea (400 g.) lime (0.8 g.) and formalin to give the desired urea-formaldehyde (U/F) ratio were mixed and the reaction mixture heated to 60° and maintained at this temperature for one hour with mechanical stirring. After cooling the solution was filtered to remove excess lime, and a portion used to determine the amount of sulphuric acid necessary to adjust the acidity of the reaction mixture to the required value. Further portions of the cold reaction mixture were then heated rapidly to 100°, the necessary acid added, and the mixture held at this temperature for the selected period of time, during which precipitation of urea-formaldehyde compounds occurred. The acid reaction was terminated by stirring in calcium carbonate (2 g.) and the resulting product dried at 80° for 24 hours.

After preliminary trials 72 samples were prepared in this way, using eight different U/F ratios from 1 : 1 to 2 : 1, with pH values of 2.5, 3.5 and 4.5 and periods of heating of 5, 15, and 30 minutes in the acid stage. Determinations of total nitrogen content, water-soluble nitrogen and free urea were made on all samples. Values for water-soluble nitrogen ranged from 4.2% to 87.5% of the total nitrogen content of the samples, the values increasing with the U/F ratio of the reaction mixture. Values for free urea similarly increased with U/F ratio, ranging from 0.7 to 27.4% of the total nitrogen content. At any one U/F ratio the soluble nitrogen content of the products decreased with increasing acidity, the effect being most marked at the lower U/F ratios. The period of heating under acid conditions also affected the soluble nitrogen content of the samples at the lower U/F ratios, the solubility decreasing as the duration of the acid reaction was increased.

Soil tests in which the rates of mineralization of nitrogen from urea-formaldehyde compounds were compared soon showed that any effect of period of reaction under acid conditions lay within the limits of experimental error of the incubation tests. The experiment was therefore modified to include only one period of acid reaction (five minutes), the 24 samples including 8 different U/F ratios and 3 pH values. A summary of the results is given in Table I.

The results show that the rate and extent of decomposition of the samples increased with increasing initial U/F ratio ; for any one U/F ratio decomposition in the soil increased with decreasing acidity. The percentage mineralization of nitrogen in the soil tests was closely correlated with the water-soluble nitrogen content of the urea-formaldehyde samples, and rarely exceeded the latter values.

None of the products prepared by the 2-stage procedure described can be regarded as entirely satisfactory as a slow-acting nitrogenous fertilizer in the soil used in these tests. Thus a high degree of availability in the soil was only attained by samples having a high content of water-soluble nitrogen, these being relatively quickly decomposed in the soil. Further urea-formaldehyde samples were therefore prepared at the same 8 U/F ratios from 1 : 1 to 2 : 1, these undergoing (1) alkaline reaction only (2) acid reaction only and (3) successive periods of alkaline and acid reaction. The experimental procedure corresponded on a reduced scale to the appropriate parts of the 2-stage reaction procedure already described ; the acid stage was limited to treatment for 5 minutes of pH 4.5. No precipitation occurred during reaction under alkaline conditions, and the resulting solution was diluted and appropriate aliquots transferred to the soil for mineralization tests ; the results are given in Table II. The results for products undergoing acid reaction only are given in Table III and for the complete 2-stage preparations in Table IV. A further batch of samples was prepared by leaching out the water-soluble constituents of the 2-stage preparations, the results of the soil incubation tests on the washed products being given in Table V. The soluble constituents of the 2-stage preparations were also tested by incubating aliquots of the aqueous extracts with soil (Table VI).

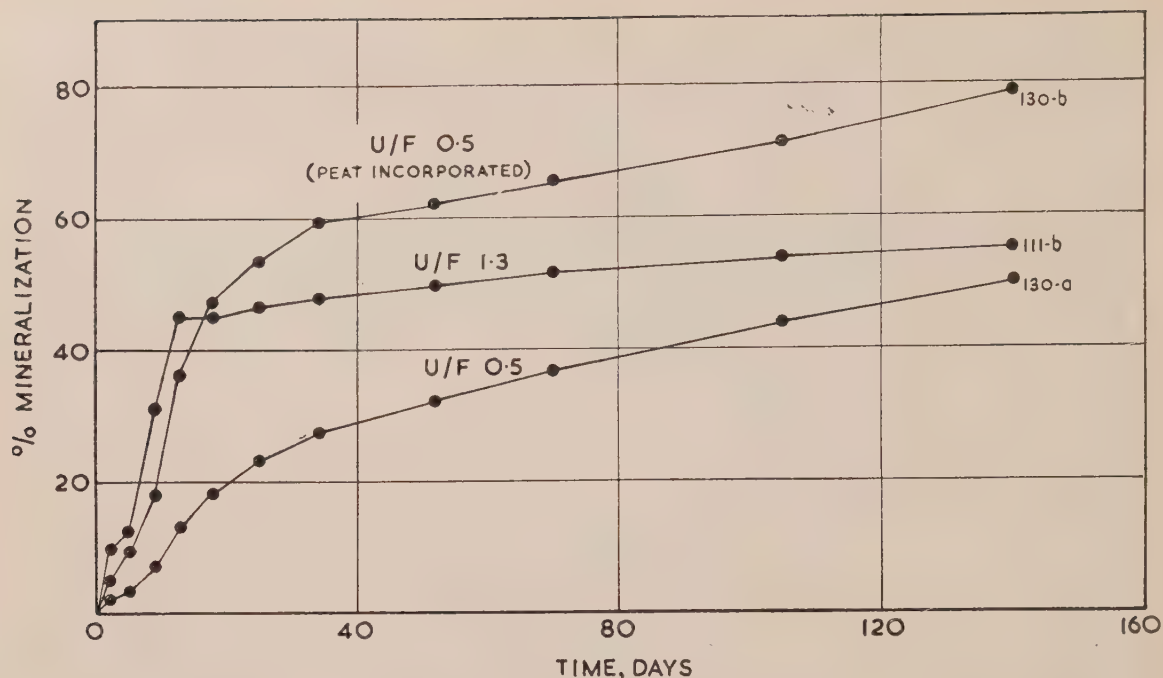


Fig. 1. Mineralization of the nitrogen of urea-formaldehyde samples prepared at a U/F ratio of 0.5, with and without peat (samples 130-a and 130-b respectively). The results for sample 111-b, included for comparison, show the less satisfactory form of mineralization curve characteristic of the earlier preparations

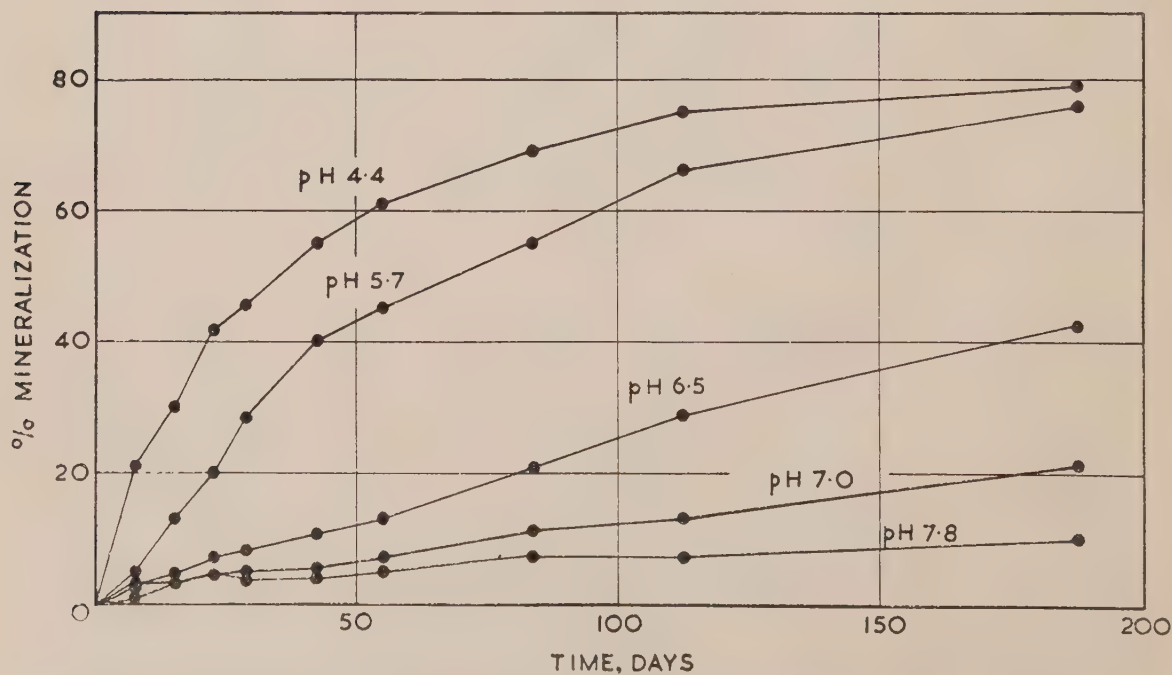


Fig. 2. Mineralization of the nitrogen of a sample of urea-formaldehyde plastic waste in five soils having initial pH values ranging from 4.4 to 7.8

TABLE I
THE PERCENTAGE MINERALIZATION OF THE NITROGEN OF SOME UREA-FORMALDEHYDE COMPOUNDS PREPARED
BY SUCCESSIVE REACTION UNDER ALKALINE AND ACID CONDITIONS

Sample Number	U/F ratio	* pH	Period of Incubation in days					
			3	6	10	18	74	186
74-a	2.0 : 1	4.5	18	34	64	69	73	79
75-a	"	3.5	20	37	64	68	74	80
76-a	"	2.5	21	36	64	68	70	76
77-a	1.8 : 1	4.5	21	35	63	68	70	81
78-a	"	3.5	17	32	56	63	70	80
79-a	"	2.5	17	32	54	58	63	74
80-a	1.6 : 1	4.5	15	31	57	61	72	73
81-a	"	3.5	13	24	49	52	60	68
82-a	"	2.5	15	26	46	49	55	62
83-a	1.5 : 1	4.5	13	24	48	53	61	72
84-a	"	3.5	13	25	44	48	51	60
85-a	"	2.5	13	24	37	40	42	48
86-a	1.4 : 1	4.5	9	16	37	41	44	63
87-a	"	3.5	8	15	36	40	47	55
88-a	"	2.5	9	16	31	34	38	50
89-a	1.3 : 1	4.5	8	14	33	38	43	44
90-a	"	3.5	8	14	28	34	37	42
91-a	"	2.5	8	12	26	28	34	37
92-a	1.2 : 1	4.5	7	11	25	28	36	38
93-a	"	3.5	7	11	20	21	25	27
94-a	"	2.5	6	11	19	20	21	28
95-a	1.0 : 1	4.5	4	9	17	17	18	25
96-a	"	3.5	4	7	12	13	14	18
97-a	"	2.5	3	5	6	9	12	11

* pH of the acid reaction after preliminary reaction in the presence of lime.

TABLE II
THE PERCENTAGE MINERALIZATION OF NITROGEN IN SOIL INCUBATION TESTS ON THE PRODUCTS OF REACTION
OF UREA WITH FORMALDEHYDE UNDER ALKALINE CONDITIONS

Sample Number	U/F ratio	Period of Incubation in days				
		2	5	9	20	38
106-a	2.0 : 1	73	76	84	93	91
107-a	1.8 : 1	71	75	82	91	92
108-a	1.6 : 1	67	76	81	94	92
109-a	1.5 : 1	68	75	83	90	92
110-a	1.4 : 1	63	75	84	91	92
111-a	1.3 : 1	59	78	82	88	92
112-a	1.2 : 1	63	80	84	87	92
113-a	1.0 : 1	56	78	80	86	90

TABLE III
THE PERCENTAGE MINERALIZATION OF NITROGEN IN SOIL INCUBATION TESTS ON UREA-FORMALDEHYDE
COMPOUNDS PREPARED UNDER ACID CONDITIONS

Sample Number	U/F Ratio	Soluble* N, %	Urea-N* %	Period of incubation in days					
				2	5	9	13	34	139
106-e	2.0 : 1	79	27	23	30	57	69	75	77
107-e	1.8 : 1	77	23	19	29	50	62	69	71
108-e	1.6 : 1	69	17	16	20	42	51	58	62
109-e	1.5 : 1	62	15	13	16	40	46	52	53
110-e	1.4 : 1	56	11	11	16	32	40	46	46
111-e	1.3 : 1	44	10	8	13	24	31	37	35
112-e	1.2 : 1	42	7	8	12	22	29	32	32
113-e	1.0 : 1	20	2	3	5	10	12	16	12

*Expressed as a percentage of the total nitrogen content of the samples

TABLE IV

THE PERCENTAGE MINERALIZATION OF NITROGEN IN SOIL INCUBATION TESTS ON UREA-FORMALDEHYDE COMPOUNDS PREPARED BY SUCCESSIVE REACTION UNDER ALKALINE AND ACID CONDITIONS

Sample Number	U/F Ratio	Soluble* N, %	Urea-N* %	Period of incubation in days					
				2	5	9	13	34	139
106-b	2.0 : 1	85	28	24	28	58	78	88	87
107-b	1.8 : 1	83	19	16	19	49	72	76	85
108-b	1.6 : 1	75	15	15	13	43	60	66	80
109-b	1.5 : 1	70	15	13	16	42	59	64	75
110-b	1.4 : 1	64	11	11	13	34	48	52	60
111-b	1.3 : 1	60	10	10	12	31	45	48	55
112-b	1.2 : 1	45	6	7	7	18	27	30	36
113-b	1.0 : 1	26	2	3	4	10	13	14	15

*Expressed as a percentage of the total nitrogen content of the samples

TABLE V

THE PERCENTAGE MINERALIZATION OF NITROGEN IN SOIL INCUBATION TESTS ON THE INSOLUBLE FRACTIONS OF UREA-FORMALDEHYDE COMPOUNDS PREPARED BY SUCCESSIVE REACTION UNDER ALKALINE AND ACID CONDITIONS

Sample Number	U/F Ratio*	Period of incubation in days						
		5	9	13	18	25	69	139
106-d	2.0 : 1	0	1	23	44	54	64	74
107-d	1.8 : 1	0	1	14	30	37	54	62
108-d	1.6 : 1	0	1	13	29	35	47	60
109-d	1.5 : 1	0	1	10	28	35	47	56
110-d	1.4 : 1	0	0	10	18	21	33	37
111-d	1.3 : 1	0	1	9	16	20	32	35
112-d	1.2 : 1	0	1	4	7	9	16	24
113-d	1.0 : 1	0	0	1	3	2	3	8

*Initial U/F ratio of reaction mixture

TABLE VI

THE PERCENTAGE MINERALIZATION OF NITROGEN IN SOIL INCUBATION TESTS ON THE WATER-SOLUBLE FRACTIONS OF UREA-FORMALDEHYDE COMPOUNDS PREPARED BY SUCCESSIVE REACTION UNDER ALKALINE AND ACID CONDITIONS

Sample Number	U/F* Ratio	Level of** application	Period of incubation in days				
			5	9	13	34	139
106-c	2.0 : 1	9.83 mg	34	60	65	77	84
107-c	1.8 : 1	9.38 "	27	52	61	76	87
108-c	1.6 : 1	8.21 "	26	49	56	67	81
109-c	1.5 : 1	7.71 "	24	47	53	67	75
110-c	1.4 : 1	7.10 "	21	41	45	60	76
111-c	1.3 : 1	6.39 "	24	41	43	59	78
112-c	1.2 : 1	4.90 "	18	33	33	41	61
113-c	1.0 : 1	2.60 "	18	29	28	38	51

*Initial U/F ratio of reaction mixture

**mg. nitrogen applied per flask containing 75 g. moist soil

The results for the soluble products of the alkaline reaction (Table II) show very rapid mineralization, over 90% of the nitrogen applied to the soil being recovered in inorganic form. The rate of mineralization of nitrogen increased with increasing U/F ratio, this effect probably being due in part to the presence of unreacted urea.

The results of soil incubation tests on the urea-formaldehyde products prepared under acid conditions (Table III) show that even a short period of reaction renders much of the product too inert to be of practical value as a nitrogenous fertilizer. Only at the higher U/F ratios (1.6 to 2.0) was a satisfactory degree of decomposition attained in the soil tests, and relatively little mineralization of nitrogen occurred after the first 2 to 3 weeks.

Comparison of the data for the products of successive alkaline and acid reaction (Table IV) with those for the acid stage alone (Table III) shows that at initial U/F ratios above 1.2 : 1 the two-stage procedure yielded products showing slightly higher availability in the soil tests. The form of the mineralization curves is still not to be regarded as satisfactory, however, a high degree of mineralization of nitrogen being accompanied by high initial rates of decomposition.

Soil incubation tests on the 2-stage products of successive alkaline and acid reaction periods, after leaching away the more soluble constituents, are summarized in Table V. Removal of these soluble constituents results in a lag-period of about nine days before mineralization of nitrogen commences, after which inorganic nitrogen was liberated in amounts increasing with initial U/F ratio. The maximum values recorded for percentage mineralization of the nitrogen of these washed samples are not as high as those for the original 2-stage preparations. Perhaps the most interesting feature of these results is that, despite the fact that the original 2-stage preparations in general decomposed in the soil to an extent approximating to their content of water-soluble nitrogen, any assumption that decomposition in the soil is mainly confined to the initially water-soluble constituents is probably unjustified, since the washed products also decompose to an appreciable extent.

The results of soil incubation tests on the soluble constituents removed by extracting the 2-stage urea-formaldehyde preparations with water are given in Table VI. In this experiment aliquots of the filtrates were pipetted on to the soil, further aliquots being used to determine the level of application of nitrogen. The percentage mineralization of the nitrogen of these soluble fractions increased with initial U/F ratio; this result may in part be due to the content of unreacted urea in the original samples (Table IV). The main conclusion to be drawn from these results is that the water-soluble nitrogenous constituents of the urea-formaldehyde samples are not completely mineralized in this soil (pH approximately 7.3), particularly at the lower U/F ratios, nor was their rate of mineralization as high as might be expected.

In view of the increased availability in the soil of urea-formaldehyde products undergoing a preliminary reaction under alkaline conditions prior to acidification, attempts were made to obtain more marked improvements by varying the conditions of preparation. The results of these experiments will not be presented here in detail; the main conclusion was that at an initial U/F ratio of 1.2, but not at 1.5, the availability of the products as shown by soil tests was increased considerably by a more vigorous alkaline reaction (80° for 3 hours) followed by acid reaction at a lower temperature (40°).

Many other methods for the preparation of urea-formaldehyde compounds have been examined. Experiments on the reaction of urea with formaldehyde under acid conditions, using high U/F ratios (4 and 2.5) and low pH values (pH 1)³, proved disappointing. Attention was later directed to products prepared at initial U/F ratios of less than 1. These materials at once appeared to be far more satisfactory than any of the previous products examined, and are described in the next section.

Urea-formaldehyde Products Prepared at U/F ratios < 1.

The products of reaction between urea and formaldehyde at a molar U/F ratio of 0.5:1 were examined, the preparation being based on the normal methods of the plastics industry for the production of stable water-soluble resins.

Urea (100 g.) was dissolved in formalin to give a U/F ratio of 0.5:1, the solution being adjusted to pH 5.5 with caustic soda and refluxed for 1 hour. The resulting solution was adjusted to pH 7 and dehydrated under reduced pressure, yielding a thick syrup which was dried for 3 days at 80° (Sample 130-a).

The results of soil incubation tests on this material are given in Fig. 1. Data for a typical product (Sample 111-b) prepared by successive periods of alkaline and acid reaction as previously described are also included for comparison, the sample being chosen so as to show approximately the same degree of decomposition within the period of the tests. The mineralization curve for the latter sample (111-b) shows that, after an initial period of rapid decomposition, the amounts of nitrogen subsequently released were relatively small. In contrast, the product prepared at a U/F ratio of 0.5 (Sample 130-a) shows a more uniform rate of mineralization of nitrogen throughout; even in the later stages of the tests mineralization of nitrogen continued at an appreciable rate, suggesting that maximum decomposition was not attained within the duration of the experiment.

Also shown in Fig 1 are the results of soil tests on a further product prepared at a U/F ratio of 0.5:1 (Sample 130-b), differing only from the procedure described for sample 130-a by the incorporation of peat to facilitate drying of the partially dehydrated resin; the inclusion of 5% (w/w) of peat shortened the drying time from 3 days to 1 day. The product (130-b) showed a high degree of availability in the soil, though its rate of decomposition is too high to be of value as a slow-acting fertilizer. The result suggests, however,

that considerable control over rates of decomposition may subsequently be obtained by varying the rate of dehydration of the products either with or without incorporation of an inert filler.

Urea-formaldehyde compounds of the type described in this section are considered to be the most promising of all the materials so far examined, and further investigations are in progress. The products differ from those previously described in that the reaction mixture has a low U/F ratio, and also in that no precipitation of polymerized material occurs during the reaction. When a higher U/F ratio (1:1) is used in such preparations, considerable precipitation occurs during the reaction and soil incubation tests indicate an unsatisfactory product.

Mineralization of the Nitrogen of Urea-formaldehyde Compounds in relation to Soil pH

In the course of these investigations 3 samples of urea-formaldehyde plastic waste ("flash") were submitted for examination in connection with some trials by the Forestry Commission. On testing these materials in the market garden soil (pH approximately 7.3) normally used by us, very little mineralization of nitrogen resulted. Further tests were accordingly made in more acid soils such as used in the Forestry Commission experiments. Preliminary tests soon shown marked variations in the rates of decomposition of urea-formaldehyde samples in different soils. An experiment was therefore made in which rates of mineralization of nitrogen were compared in 20 soils having initial pH values ranging from 3.9 to 7.8. Two samples of urea-formaldehyde were used, sample A being prepared at a U/F ratio of 0.5 as in the preceding section and sample B consisting of plastic waste. Determinations of ammonia and nitrate in the soils were made after 9 periods of incubation from 1 to 26 weeks. An account of this work is being prepared for publication elsewhere, and only a summary of the results will be presented here.

TABLE VII
MINERALIZATION OF THE NITROGEN OF TWO SAMPLES OF UREA-FORMALDEHYDE IN 20 SOILS

Soil Number	Initial pH of soil	% N mineralized in 3 weeks		Maximum % N mineralized	
		Sample A	Sample B	Sample A	Sample B
1	7.8	17	5	42	10
2	7.8	16	3	39	16
3	7.7	20	5	56	19
4	7.6	14	5	36	9
5	7.5	28	5	65	17
6	7.3	25	3	60	18
7	7.0	27	4	65	21
8	6.5	40	7	85	42
9	6.2	61	20	95	76
10	6.0	64	23	93	76
11	5.9	54	19	82	67
12	5.7	63	20	91	76
13	5.6	62	31	87	76
14	5.4	56	33	76	74
15	5.0	44	21	80	67
16	4.5	56	38	77	75
17	4.4	68	42	87	79
18	4.2	71	51	78	75
19	4.1	57	40	81	70
20	3.9	74	51	94	69

The percentage mineralization of the nitrogen of samples A and B on incubation with soil for 3 weeks is given in Table VII as a measure of the initial rates of decomposition in the various soils, together with values for the maximum percentage mineralization of nitrogen within the period of the experiment.

The results indicate that the rates of decomposition increase with increasing soil acidity. Sample B, consisting of plastic waste, decomposed more slowly in the soil than sample A, but a high degree of availability was attained in soils having initial pH values below 6.5. The form of the mineralization curves is shown in Fig. 2 for sample B in 5 soils having initial pH values from 4.4 to 7.8. The marked effect of soil pH on the decomposition of urea-formaldehyde materials in soil is readily apparent.

Considerable changes in pH accompanied the mineralization of nitrogen. Thus with soils in which nitrate accumulated the pH decreased markedly unless sufficient carbonate was also present. In the more acid soils, in which ammonia tended to accumulate, the pH was increased by decomposition of urea-formaldehyde.

Correlation coefficients relating soil pH and percentage mineralization of nitrogen are given for various periods of incubation in Table VIII, using the initial soil pH values for the early stages of mineralization and the pH values of the treated soils for longer periods of incubation. Highly significant negative correlations were found throughout. It is of interest that the solubility of urea-formaldehyde samples in buffer solutions also increases with the degree of acidity. Thus after immersion of sample B in buffer solutions for 2 days the soluble nitrogen, expressed as a percentage of the total nitrogen content of the sample, increased from 7% at pH 8 to 38% at pH 4.

TABLE VIII
CORRELATION COEFFICIENTS RELATING SOIL pH AND % MINERALIZATION OF ADDED NITROGEN

Period of incubation in weeks	Sample A	Sample B
1*	-0.885	**
2*	-0.920	-0.910
4*	-0.837	-0.948
8	-0.887	-0.962
16	-0.899	-0.974
26	-0.727	-0.965

*Correlated with initial soil pH

**Non-linear relationship

Summary of Results

1. Following earlier work on the properties of urea-formaldehyde materials prepared by reaction under acid conditions at U/F ratios of 1-3, ¹, ² alternative methods of preparation have now been examined.

2. Reaction of urea with formaldehyde under alkaline conditions, followed by further reaction under acid conditions, yielded products having a somewhat higher degree of availability in the soil than samples prepared under acid conditions alone.

3. More detailed examination of the 2-stage reaction showed that the soluble products of the alkaline reaction stage are readily decomposed in the soil. Subsequent acid treatment causes precipitation and renders part of the nitrogen content unavailable in the soil. Not all the nitrogen of the soluble fraction of the 2-stage preparations is readily mineralized in soil at the lower U/F ratios; at the higher U/F ratios, however, the soluble fraction is readily mineralized and the initially insoluble fraction also shows a relatively high availability in the soil.

4. Urea-formaldehyde compounds prepared at a U/F ratio of 0.5 and a pH of 5.5, the resulting water-soluble resin being dehydrated to yield a vitreous solid, are considered to be the most promising materials so far examined as possible slow-acting fertilizers.

5. The decomposition of urea-formaldehyde samples in soil is shown to be dependent on soil pH, mineralization of nitrogen increasing with the degree of acidity. The solubility of urea-formaldehyde samples in buffer solutions also increases with acidity within the pH range 8-4.

6. In view of the similarity of the relationship to pH found for urea-formaldehyde samples both in soil incubation tests and buffer-solubility tests, the initial stages in the decomposition of urea-formaldehyde compounds in the soil may be chemical rather than biological.

7. Because of the relationship between mineralization of nitrogen and soil pH it is unlikely that any one urea-formaldehyde sample can prove satisfactory as a slow-acting fertilizer in all soils. Thus urea-formaldehyde plastic wastes, though of little value in the neutral or alkaline soils frequently encountered in glasshouse practice, should prove of considerable value for crops grown under somewhat acid conditions.

Acknowledgments

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2. "BLOTCHY RIPENING" OF TOMATO FRUIT: A PRELIMINARY REPORT ON SOME CHEMICAL ASPECTS OF THE DISORDER

D. M. MASSEY and G. W. WINSOR

Blotchy ripening must now be regarded as one of the major unsolved problems in tomato growing. It is therefore somewhat surprising that the subject has apparently received rather less attention from research workers than its importance clearly warrants. Only a brief review of some of the main contributions to our knowledge of the disorder will be given here; papers dealing specifically with blotchy ripening are relatively few in number, though references to the disorder or information likely to be of value in its elucidation may be found widely distributed throughout the literature of the crop

A description of blotchy ripening was given by Bewley and White¹ (1926); it was noted that, unlike "green back," the green areas were not confined to the region adjoining the calyx but arose anywhere over the surface of the fruit. The differently coloured areas merged gradually without an abrupt line of demarcation, in contrast to the markings attributed to mosaic. It was recorded that the vascular bundles in the hard green areas were sometimes brown and necrotic. "Waxy patch" was recognized as a more severe form of the disorder in which some areas of the fruit had a waxy or glassy appearance instead of being green and opaque. The vascular bundles beneath these waxy areas were invariably necrotic. The presence of corky cells and gaps in the parenchyma adjoining the vascular bundles in the walls of blotchy fruit was described and illustrated. Manurial trials demonstrated that the incidence of blotchy ripening could be markedly reduced by suitable applications of potash and nitrogen, but other factors, probably climatic in nature, were also considered to be associated with the disorder.

Seaton (1934) found that the percentage of blotchy fruit increased with the spacing between the plants, as did the mean leaf area per plant.² Seaton and Gray (1936) published an account of histological studies of tomato fruit affected by blotchy ripening.³ These authors described cavities in the vascular bundles of blotchy fruit walls due to collapse of the associated parenchymatous cells, and also bands of discoloured cellular material occurring between the epidermis and the bundles. Blotchy ripening was attributed primarily to conditions arising from the withdrawal of water from the fruit during periods of excessive transpiration occurring 2 to 5 days before the fruit ripens; deficiencies of potassium and nitrogen were considered to be only of secondary importance.

Further observations on the incidence of blotchy ripening were published by White⁴ (1938), it being suggested ". . . that blotchy ripening is not due directly to lack of potassium or nitrogen but to metabolic changes that are counteracted by increase of light." A significant negative correlation was found between the incidence of blotchy ripening and the mean daily hours of sunshine, though one year (1921) was noted in which blotchy fruit was exceptionally prevalent despite an abnormally high number of hours of sunshine. Potassium starvation was considered to affect the translocation of carbohydrates from the leaves of tomato plants, and also the conversion of starch to sugars within the fruit walls. It was further concluded that blotchy ripening was not invariably associated with structural disorganization of the tissues, the latter apparently following rather than preceding failure to ripen.

Selman⁵ (1943), studying mosaic infection of the tomato, found ". . . evidence of differing responses to potash manuring in the amounts of blotchy fruit produced by infected and by control plants. High potash manuring tended to reduce the incidence of blotchy ripening in infected plants, whereas similar quantities of potash applied to the controls tended to increase the percentage of blotchy fruit relative to that produced by medium potash manuring of similar plants." These observations are of interest in view of the widespread occurrence of mosaic infection in tomato crops under glass.

More recently a series of papers on the subject of "Cloud" or vascular browning of tomatoes has been published in New Zealand by Kidson and Stanton,^{6, 7, 8}. During a visit by Dr. Kidson it was confirmed that the disorder referred to is similar to "blotchy ripening" in this country. The term cloud apparently refers to the appearance of a network of necrotic tissues within the outer walls of the fruit; rather more emphasis is thus placed on the presence of vascular disorder, and the term "cloud" would presumably not include the less marked cases of irregular colouration unaccompanied by necrosis.

"Cloud" in glasshouse tomatoes was increased by heavy watering, soil sterilization and raw organic manures, and decreased by heavy dressings of potash in the winter or by frequent applications of nitrogenous fertilizers and potassium or calcium chloride throughout the season.⁶ These beneficial treatments tend to produce a thinner-stemmed, less rank type of growth and a slightly reduced crop yield. No relationship was found between the incidence of "cloud" and the inorganic constituents of either fruit or leaves,

but susceptible plants in general had an abnormally low dry-matter content. Kidson⁹ has since shown that blotchy ripening is not due, as had previously been suggested, to manganese toxicity.

The stage of development of the fruit at which the disorder is recognized is a matter of considerable interest. Thus Seaton and Gray³ state that the disorder is apparently restricted to practically mature fruits, the first evidence being observed only after the fruit begin to colour. Dissection of immature fruit showed no detectable signs of the development of blotchy ripening. Kidson⁸ states that the earliest traces of cloud were found on fruit 50-55 days old and apparently only a few days from ripening; no signs were found in younger fruit. No cloud developed in green fruit after picking, but in one experiment it was recorded that 30% of the green fruit showed cloud at the time of picking.

If recognition of blotchy ripening is to be based on uneven pigmentation of the fruit, it can by definition only be identified in fruit which has begun to colour. If, however, emphasis is placed on vascular browning, the period of observation is greatly extended. Vascular browning, though most frequently observed in ripe fruit, certainly occurs in green tomatoes, sometimes giving rise to a discolouration of the outer walls often termed "bronzing." A form of vascular browning known as "gray-wall" has been described in Florida^{10, 11}, affecting fruit ". . . of all sizes larger than one-half inch"¹⁰; uneven ripening was common and apparently conditioned in amount by the severity of the internal browning. No definite conclusions on the relationship between these disorders can be given at present, but it is possible that "bronzing" arises in green fruit from the same cause as blotchy ripening, and that "gray-wall" may also be related to one or both of these conditions.

Scope of the Present Investigation

The results to be reported form part of an investigation of the composition of tomato fruit in relation to the incidence of blotchy ripening. The subject has been considered under four headings, namely (1) comparison of the composition of normal and blotchy tomato fruit, (2) comparison of the variously coloured portions of the walls of blotchy fruit, (3) the relationship of the results of (1) and (2) to the normal processes of ripening and (4) comparison of the composition of fruit of different varieties in relation to the incidence of blotchy ripening.

The results which follow form a summary of the data so far obtained under headings (1) and (2).

EXPERIMENTAL PROCEDURE

The period in which blotchy fruit would be available for experimentation in any one season being somewhat unpredictable, it was considered necessary to evolve methods by which relatively large numbers of samples could be examined as available without delay. For this purpose examination of expressed sap seemed eminently suitable, the fresh material being frozen on arrival at the laboratory. Further samples of fruit were dried at 80° C., yielding both data for the percentage of dry matter and also material which could be stored for subsequent examination when supplies of fresh fruit were no longer available. A limited quantity of fruit was also preserved in alcohol for the determination of carbohydrates.

In outline the procedure for examination of expressed sap was as follows :

Fruit samples were frozen overnight in sealed jars. The material was then thawed out rapidly and pressed, determinations of pH and conductivity being made immediately. The remainder of the sap was centrifuged and filtered through glass wool. Aliquots of sap were then taken for the determination of titratable acidity, reducing sugars, total nitrogen and potassium. Further samples were oven-dried for the determination of total solids in the sap, and subsequently ignited for the determination of ash content.

For the investigations now reported all fruit samples were of variety Potentate, collected at the normal commercial picking stage. All samples described as "blotchy" showed irregular green or yellow-green and red areas, associated to a varying degree with vascular browning of the fruit walls. Some degree of abnormality was found in the walls of all samples of blotchy fruit used in this investigation. Where the colour contrast in blotchy fruit was really prominent, cutting invariably revealed either cavities or brown areas in the walls. In milder instances of the disorder abnormality of the fruit walls was limited to a pale white spongy or corky appearance in the region of the vascular bundles.

RESULTS

The Composition of Blotchy and Normal Fruit

Paired samples consisting of 2-3 lbs. of blotchy fruit and a similar quantity of normal fruit were collected from 16 nurseries in the Lea Valley during May, June and July. The scheme for analysis of expressed plant sap, referred to in the preceding paragraphs, was applied to all samples; determinations of

dry matter in the fruit were also made. A summary of the results is given in Table I, in which the mean values for 16 samples each of normal and of blotchy fruit are compared; the statistical significance of the differences between blotchy and normal fruit is also indicated in the Table.

TABLE I
MEAN VALUES FOR PERCENTAGE DRY MATTER AND FOR CONSTITUENTS OF THE
EXPRESSED SAP OF NORMAL AND BLOTCHY FRUIT FROM 16 NURSERIES

	Normal	"Blotchy"	Significance*
Dry matter in fruit, % ...	5.72	5.26	P—0.01
Total solids in sap, g./100 mls. ...	4.35	3.80	0.001
Reducing sugars, g./100 mls. ...	2.77	2.35	0.01
pH ...	4.32	4.45	0.001
Titratable acidity** ...	9.2	7.8	0.001
Nitrogen, g./100 mls. ...	0.078	0.067	0.02
Potassium, g./100 mls. ...	0.309	0.296	0.1
Conductivity, K x 10 ⁻³ mhos. ...	7.03	6.86	—
Ash, g./100 mls. ...	0.530	0.517	—
Sap volume, mls./100 g. ...	64.4	64.6	—

* Significance of differences between normal and blotchy fruit, using "Student's" method for paired data.

** Mls. N/10 NaOH per 10 mls. sap.

The results show that the normal fruit had a higher content of dry matter than blotchy fruit; this result is in agreement with those obtained by Kidson in New Zealand⁷. The concentration of soluble solids in the sap of normal fruit was also higher than for blotchy fruit, values for sap solids and percentage dry matter in the fruit being closely correlated. Reducing sugars, which constitute a high proportion of the total soluble material in the sap, were similarly present at a higher concentration in normal than in blotchy fruit. As shown by the higher titratable acidity and lower pH values, the sap of normal fruit had a higher content of acids than that of blotchy fruit, the differences being highly significant in both instances. The observed differences in pH were relatively small, but without exception the paired samples from all 16 nurseries showed a lower pH in the sap of the normal fruit. The concentration of nitrogenous compounds was, in general, higher in the sap of normal than of blotchy fruit. Less variation was found in the content of potassium in the expressed sap, and differences between normal and blotchy fruit failed to achieve statistical significance. Neither the electrical conductivity nor the ash content of the expressed sap was significantly lower in the blotchy fruit.

Comparison of the Variously coloured portions of the Walls of Blotchy Tomato Fruit

The outer walls of blotchy fruit at commercial picking stage were dissected and graded into three batches on the basis of colour. The graded samples were frozen without delay and the expressed sap examined as in the preceding section. The results for two batches of blotchy fruit, obtained in June and July respectively, are given in Table II.

TABLE II
ANALYSES OF SAP EXPRESSED FROM VARIOUSLY COLOURED PORTIONS
OF THE WALLS OF BLOTCHY FRUIT

	Sample A			Sample B		
	Red	Yellow	Green	Red	Yellow	Green
Sap solids, g./100 mls. ...	3.41	3.20	2.75	3.32	3.05	2.86
Reducing sugars, g./100 mls. ...	2.29	2.09	1.64	2.19	1.96	1.84
pH ...	4.49	4.57	4.70	4.33	4.40	4.52
Titratable acidity* ...	5.9	5.1	4.5	5.1	4.6	4.2
Nitrogen, g./100 mls. ...	0.068	0.059	0.052	0.065	0.054	0.054
Potassium g./100 mls.	0.250	0.252	0.264	0.238	0.236	0.234
Conductivity, mhos x 10 ⁻³ ...	5.99	6.12	6.44	5.65	5.83	5.97
Ash, g./100 mls. ...	0.427	0.422	0.453	0.421	0.422	0.372

* mls. N/10 NaOH per 10 mls. sap.

The data for total solids in the sap show for both samples a progressive decrease from the red to the green areas of fruit wall, with related changes in the concentration of reducing sugars. The acidity of the

sap, as measured both by titration and by pH determinations, also decreased from the red to the green areas. The nitrogen content of the sap decreased with colour from red to green in sample A, and was higher in the sap of red areas than of yellow or green areas in sample B; this uneven distribution of soluble nitrogenous compounds has since been confirmed for other samples. The results for potassium show considerable uniformity throughout. The electrical conductivity of the sap increased slightly from red to green areas for both the samples referred to in Table II; further work, however, has shown that this trend is not always present. The results for ash content of the sap are as yet inconclusive.

Discussion of Results

Analytical data for fruit samples from 16 nurseries, summarized in Table I, show significant differences in the dry-matter content and composition of the expressed sap of blotchy and normal fruit. The most marked differences were found in the total content of sap solids and in the concentration of organic constituents such as sugars and acids; differences in the content of inorganic constituents were less marked, as shown by the results for potassium, ash content and electrical conductivity of the sap.

The results in Table II show differences in the composition of the variously coloured portions of blotchy tomato fruit, the most interesting results again being those for total sap solids, sugars and acids; the green areas of the blotchy fruit showed lower values than the red areas in these tests, as did the whole blotchy fruit when compared with normal fruit. The distribution of potassium was apparently fairly uniform, but the nitrogenous constituents were found at higher concentrations in the red than in the green areas.

Despite marked differences in the concentration of various constituents of sap from normal and blotchy fruit, the relative proportions of these constituents were rather similar throughout. Expressed as a percentage of the total sap solids, the mean values for constituents of the sap of the 16 paired samples of fruit were as follows :

	Normal	"Blotchy"
Reducing sugars	63.5	61.7
Acids (as citric acid)	15.0	14.7
Nitrogen	1.82	1.80
Ash	12.2	13.6

Calculated in this way the proportion of sugars, acids and nitrogenous compounds was slightly lower, and the proportion of inorganic constituents slightly but significantly higher, in the sap of blotchy than of normal fruit.

The results here reported thus show that blotchy ripening is associated with a low concentration of organic constituents in the fruit, this conclusion being in accordance with the views of Kidson and Stanton⁷. Furthermore the differences so far observed between the sap of normal and blotchy fruit appear to be in the overall concentration of organic substances rather than in the relative proportions of the main constituents.

The significance of the present results and their relationship to the various cultural and environmental factors affecting the incidence of blotchy ripening are not yet fully apparent. It is difficult, however, to avoid the conclusion that, whatever the primary cause of the disorder, its effect on the fruit is associated with damage in or adjacent to the vascular bundles. The nature of this vascular damage lies outside the scope of the present investigation. It may be noted, however, that the explanation proposed by Seaton³, namely the withdrawal of water from the fruit during periods of excessive transpiration, is similar to that proposed by Ende¹² and others for a number of crop disorders.

The low dry-matter content of blotchy fruit could, at first sight, be attributed merely to impeded movement of food substances into and within the fruit through a damaged vascular system. There are reasons, however, to suggest that this is not a full explanation of the facts. Thus Kidson⁷ has shown that plants susceptible to the disorder have a low dry-matter content not only in the fruit but also in the leaves.

Whatever the mechanism of the vascular damage, we are inclined to the view that it occurs under certain physical conditions, possibly operating for relatively short periods in the life of the plant. Furthermore it seems likely that, when such conditions occur, the extent to which any injury results is related to the general growth of the plant. It may be noted that many of the factors already shown⁶ to affect the incidence of blotchy ripening are those which influence the general growth of the crop. Thus soil sterilization, heavy watering and fresh organic manures stimulated growth and increased the percentage of blotchy fruit, whereas lighter watering and very heavy dressings of various inorganic salts gave a less rank type of growth and a lower proportion of affected fruit. The percentage of dry matter in a plant may be expected to be related to the conditions of growth; evidence is already available to show that certain growth conditions

which appear to favour blotchy ripening, namely a high soil moisture content and soil sterilization⁶, can result in a lower dry-matter content in the plants^{7, 13, 14}. It has also been found that heavy applications of fertilizers, shown by Kidson⁶ to reduce the incidence of blotchy ripening, can increase the dry-matter content of the fruit^{7, 15}. Further work will be necessary, however, before a full interpretation can be given of the results so far obtained in the present investigation.

Acknowledgements.

The co-operation of all who so kindly supplied the fruit samples used in this investigation is gratefully acknowledged.

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3. STEAM STERILIZATION STUDIES

By J. N. DAVIES

Nitrogen

Studies of some of the factors influencing ammonification in steamed soils have now been concluded. Two groups of soils have been used in this investigation, namely, 18 field and garden soils having pH values ranging from 4.32 to 7.93, none of which had been steamed before, and 20 glasshouse soils with pH values ranging between 6.39 and 8.46, all of which had been steamed many times previously. Statistical analysis of the results shows that in both groups of soils the ammonia produced after incubation for three weeks was significantly correlated with the total nitrogen and organic carbon contents of the soils. The relationships between the ammonia-nitrogen produced after steaming and the total nitrogen content of the field and garden soils with and without added lime are shown in Figs. 1 and 2. A similar relationship for the glasshouse soils is shown in Fig 3. The linear regression of the ammonia produced on the total nitrogen content is shown on the diagrams. For the field and garden soils steamed with and without added lime the correlation coefficients (r) were 0.762 and 0.661, significant at $P=0.001$ and 0.01 respectively; for the glasshouse soils the correlation coefficient was 0.722 ($P=0.001$). In a further series of experiments the soil samples were deliberately contaminated after steaming, with the result that some or all of the ammonia produced was nitrified during the period of incubation. In such experiments the accumulation of inorganic nitrogen, calculated as the sum of ammonia and nitrate, was significantly correlated with the total nitrogen content of the soils; thus, for the field and garden soils steamed in the presence of added lime a correlation coefficient of 0.765 was obtained, significant at $P=0.001$.

In both groups of soils correlations between the ammonia produced after steaming and the initial soil pH, the percentage of hydrolysable nitrogen and the carbon/nitrogen ratio all failed to attain significance at the 5% level. In the glasshouse soils a significant correlation was obtained between the phosphate soluble in N/2 acetic acid and the ammonia produced ($r=0.529$, $P=0.05$), but a similar correlation in the field and garden soils was not significant at the 5% level.

Perhaps the most striking feature of the results is that the amount of ammonia produced per unit of soil nitrogen was, in general, much less in the glasshouse soils than in the field and garden soils. The only exceptions to this general relationship were certain acid maiden soils in which the activity of ammonifying organisms was almost completely suppressed by steaming. In the glasshouse soils used in this

investigation from 0.68 to 1.58% of the total soil nitrogen was ammonified, the mean value being 1.08%. The corresponding range of values for field and garden soils was from 0.02 to 4.91%, with a mean value of 2.03% of the total nitrogen. The addition of lime increased the amount of ammonia produced after steaming in acid soils but not in neutral or alkaline soils.

The difference in the amounts of ammonia produced in the two different groups of soils is considered to be due to the effect of repeated steamings on the glasshouse soils, together with the maintenance of a high pH. It seems likely that the interval between successive steamings of such soils is insufficient for the accumulation of large reserves of nitrogenous substances, probably in the form of microbial tissues or residues, which can be mineralized after steaming. In consequence, despite the high total nitrogen content of such soils, the amount of ammonia produced after steaming is comparatively small. On the other hand, where a soil rich in organic matter has remained uncultivated for a considerable time, is moderately acid and has never been steamed before, conditions appear to be most favourable for the formation of large amounts of ammonia after steaming.

It has been shown previously (J. Sci. Food Agric., 2, 268, 1951) that contamination of steamed glasshouse soils with unsteamed soil or with an aqueous suspension of unsteamed soil is followed by renewed nitrification within two or three weeks. Extension of this work to include more acid soils of the type used commercially in the preparation of propagating and potting mixtures has shown that deliberate contamination of these soils after steaming is not followed by rapid disappearance of the soil ammonia. Typical results for such a maiden soil having an initial pH of 4.4 are given in Table I.

TABLE I
AMMONIA AND NITRATE PRODUCTION (P.P.M.) IN A MAIDEN SOIL
(pH 4.4) AFTER STEAMING AND CONTAMINATING

Time, days	Unsteamed		Steamed		Steamed and contaminated	
	NH ₃ -N	NH ₃ -N	NH ₃ -N	NO ₃ -N	NH ₃ -N	NO ₃ -N
2	5.8	56.1	17.0	52.1	22.0	53.4
4	2.6	60.5	55.5	50.0	50.5	54.5
8	3.7	63.7	95.5	47.9	92.2	50.6
14	2.7	74.6	159.4	51.3	128.9	52.3
25	3.9	90.7	220.3	52.4	183.8	51.3
36	1.8	104.0	210.0	52.3	222.9	52.9
45	2.0	120.2	215.6	51.9	220.1	52.0

It will be seen that ammonification proceeded at about the same rate in steamed soil whether contaminated or not. There was no indication of renewed nitrification in the steamed contaminated soil even after incubation for nearly seven weeks.

The onset of nitrification in acid maiden soils after steaming and contamination has been found to be markedly accelerated by the addition of lime. Fig. 4 shows ammonia and nitrate production in an acid maiden soil after steaming and contaminating with and without added lime. Where lime had been applied nitrification began within three weeks of steaming and contaminating, whereas without added lime no increase in nitrate concentrations was observed and ammonification proceeded steadily throughout the incubation period.

The addition of superphosphate alone had little effect on either ammonia production in steamed soils or on the onset of nitrification after contamination.

These results will be published in detail elsewhere.

Potassium

The effect of steaming on the availability of soil potassium has been studied in various soils, including glasshouse and market garden soils and maiden loams. Distilled water and 0.5N acetic acid were used as extractants of soil potassium, a soil: extractant ratio of 1: 40 being employed. Potassium was determined directly in the extracts with a flame photometer. In some instances potassium was also determined in soil solutions obtained by displacement with alcohol. Where necessary in the laboratory investigation soil was partially sterilized by heating in an autoclave for 20 minutes at zero pressure.

Preliminary experiments with glasshouse soils and maiden loams showed that water-soluble potassium was increased as an immediate result of steaming. After incubating the glasshouse soils at 23.5°C. there was usually a fall in the concentration of water-soluble potassium. This is presumably the result of potassium fixation, as it occurred in both steamed and unsteamed soils. In the maiden loams examined, however, only small increases were observed on steaming and changes on incubation were small.

The immediate effect of steaming on the soil potassium of 14 glasshouse soils is shown in Table II. A close relationship exists between the water-soluble and acetic acid-soluble potassium in the unsteamed soils, the value of the correlation coefficient r being 0.959 significant at $P=0.001$. In the unsteamed soils

TABLE II

Soil	p.p.m. water-soluble potassium*			p.p.m. acetic acid-soluble potassium*	
	Unsteamed	Steamed	Increase due to steaming	Unsteamed	Steamed
1	455	533	78	976	976
2	712	831	119	1244	1251
3	551	609	58	1086	1112
4	461	501	40	845	845
5	587	608	21	930	938
6	534	628	94	938	919
7	393	425	32	894	903
8	318	380	62	722	701
9	467	492	25	1016	1026
10	34	40	6	107	107
11	31	35	4	71	69
12	323	335	12	715	711
13	574	600	26	1100	1100
14	629	656	27	1020	1041

* Expressed on an oven-dry soil basis

31.8–63.1% (mean value 49.8%) of the acetic acid-soluble potassium was soluble in water, as compared with 37.4–68.3% (mean value 55.0%) in the steamed soils. Changes in acetic-acid soluble potassium after steaming were small and not statistically significant. Increases in water-soluble potassium of between 4 and 119 p.p.m. were, however, observed in the soil as an immediate result of steaming. It thus seems likely that the increase in water-soluble potassium on steaming is derived from that part of the soil potassium which was initially soluble in acetic acid but not in water.

The increase in water-soluble potassium in the 14 glasshouse soils after steaming is significantly correlated with the water-soluble potassium in the unsteamed soils, the value of the correlation coefficient r being 0.564 significant at $P=0.05$. Similar data are also available for a further 20 soils in addition to the 14 glasshouse soils referred to in Table II; calculation of the correlation coefficient for the 34 soils gives a value of 0.578 significant at $P=0.001$. No relationships are apparent, however, between the increase in water-soluble potassium on steaming and either the soil pH or the total nitrogen content.

In addition to the above experiments, changes in the level of soil potassium in three glasshouse soils steamed by the Hoddesdon pipe system were followed *in situ*. Potassium was determined in 1:10 soil:water extracts and also in the soil solution obtained by displacement with alcohol. Results for the three soils are given in Table III. The data given for the unsteamed soil were in each case determined on samples taken immediately before steaming. It will be seen that steaming brought about an increase in water-soluble potassium in each soil. Increased potassium concentrations were also observed in the displaced soil solutions.

TABLE III

	Soil C			Soil D			Soil E		
	Time in days	Water sol. K* p.p.m.	Soil soln. K** p.p.m.	Time in days	Water sol. K* p.p.m.	Soil soln. K** p.p.m.	Time in days	Water sol. K* p.p.m.	Soil soln. K** p.p.m.
Unsteamed	0	181	130	0	301	304	0	151	86
Steamed	2	290	235	0	351	304	0	207	130
"	6	283	252	7	314	283	7	159	108
"	13	271	214	14	300	248	14	190	130
"	23	253	218	25	338	315	28	167	105
"	37	209	193	39	232	379	44	169	112

* Expressed on an oven-dry soil basis

** Concentration of potassium in displaced soil solution.

Fig. 1

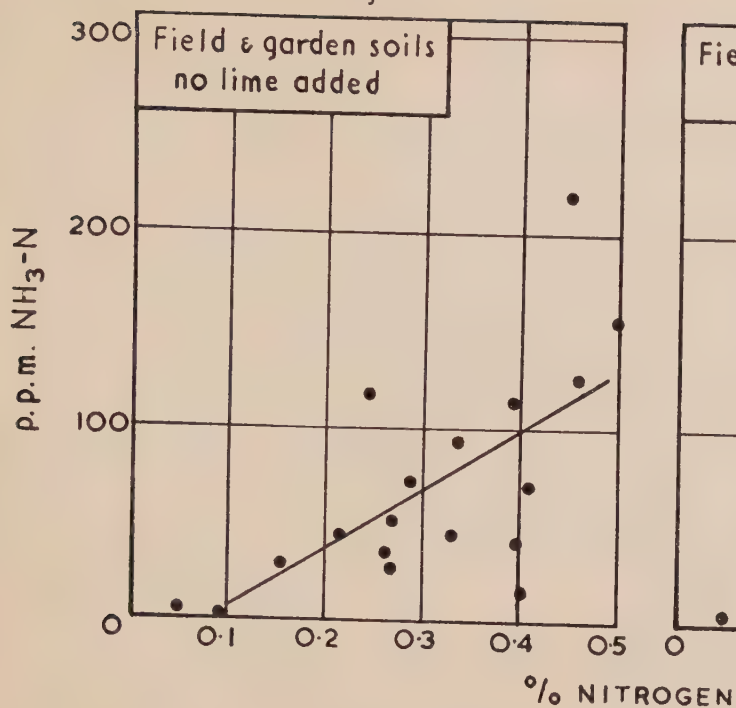


Fig. 2

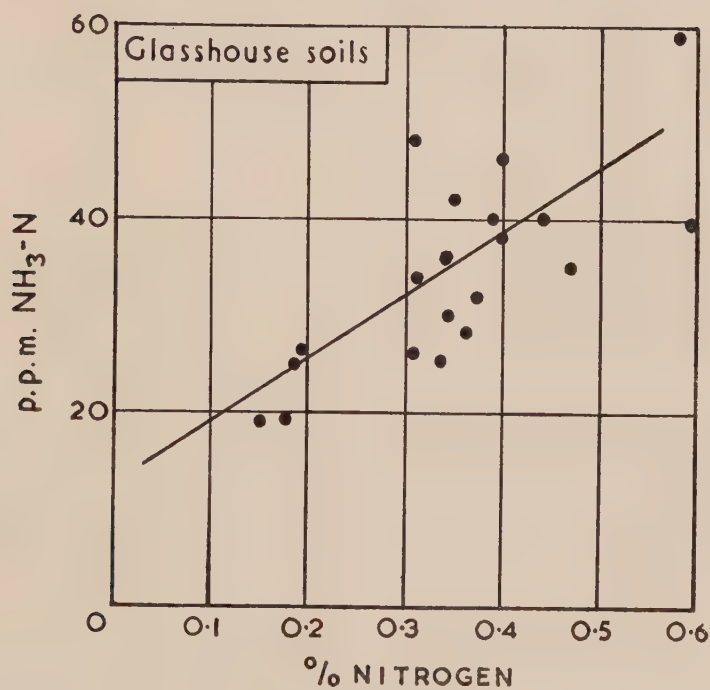
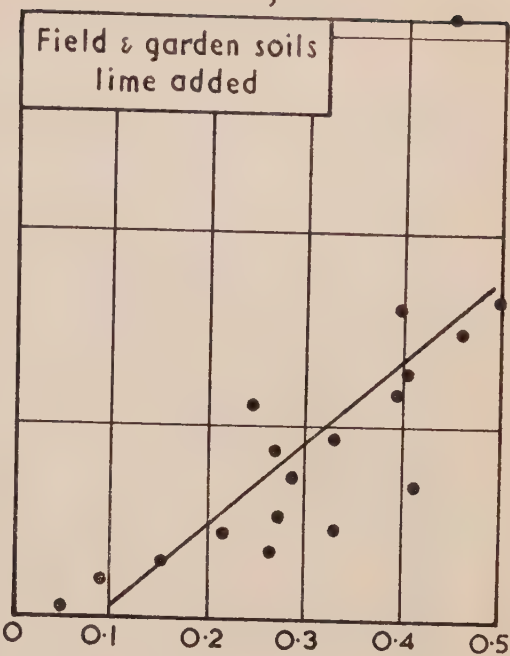


Fig. 3

Ammonia production in relation to soil nitrogen content after steaming and incubating :

Fig. 1. 18 field and garden soils

Fig. 2. The same 18 soils with lime added

Fig. 3. 20 glasshouse soils

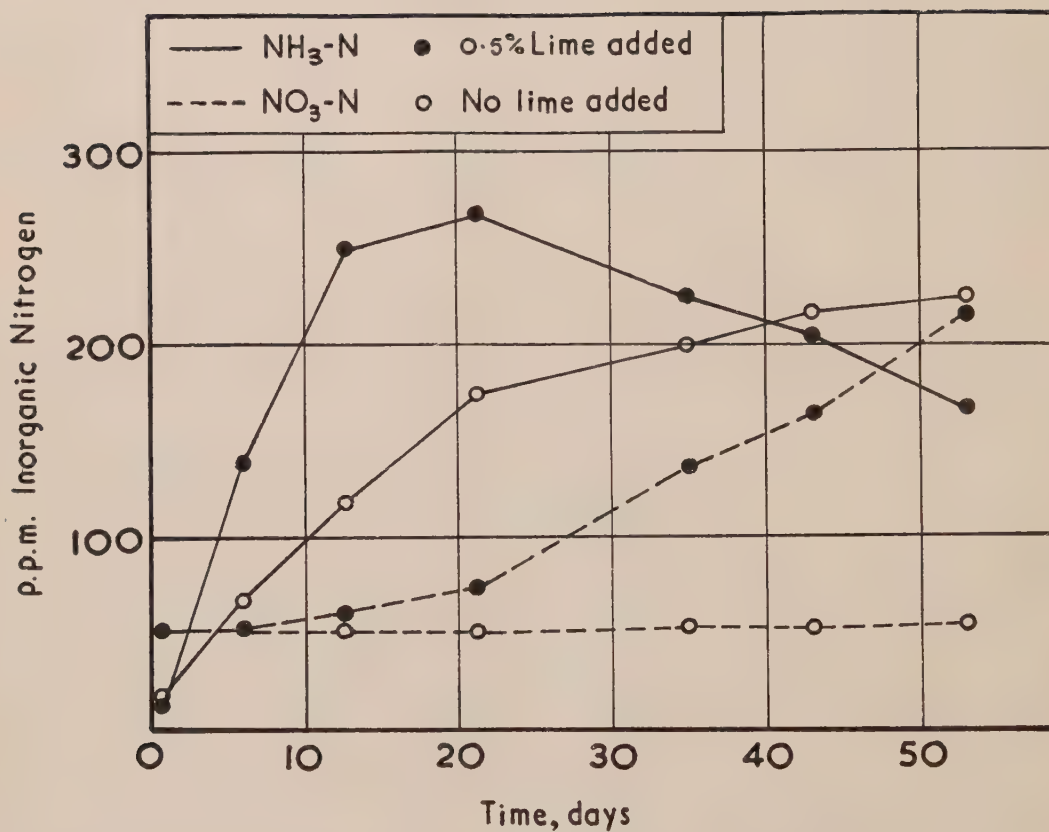


Fig. 4. Ammonia and nitrate production in an acid maiden soil after steaming and contaminating with and without the addition of lime.

4. VISUAL SYMPTOMS OF MINERAL DEFICIENCIES IN HYDRANGEA

By J. H. L. MESSING

The dependence of the colour of hydrangea blooms on the conditions of growth has been examined by numerous investigators. There appears, however, to be rather less information readily available concerning the nutritional requirements of hydrangeas, and we have been unable to find descriptions of the visual symptoms of mineral deficiencies other than those due to nitrogen, phosphorus, potassium, iron and aluminium. Studies of the visual symptoms of mineral deficiencies in hydrangeas were accordingly included in the programme of sand-culture experiments for 1954.

Rooted cuttings of two varieties, King George and Goliath, were purchased in July, 1953. After careful washing of roots, these were planted in one-gallon glazed earthenware pots filled with high purity silica sand. The plants were established in complete nutrient solution, and then dried off to winter in an unheated glasshouse. Watering was resumed on February 20th, 1954; the temperature was raised and nutrient solution applied from February 24th. All plants intended for studies of macro-nutrient deficiencies were at first supplied with complete nutrient solution; plants intended for micro-nutrient studies received only macro-nutrients until March 17th.

The various treatments were started on March 17th, the effects of the omission of nitrogen, sulphur, phosphorus, potassium, calcium, magnesium, boron, manganese and iron being studied. The effect of different concentrations of aluminium in the nutrient solution was also examined within the range 0–80 p.p.m.

The composition of the complete nutrient solution in p.p.m., as used at the start of these experiments, was as follows:—

Nitrogen	—	97	Boron	—	0.4
Phosphorus	—	22	Manganese	—	0.5
Potassium	—	75	Iron	—	3.0
Calcium	—	87	Zinc	—	0.03
Magnesium	—	24	Copper	—	0.03
Sulphur	—	32	Molybdenum	—	0.02

At the beginning of April a marked interveinal chlorosis developed rapidly in all treatments other than those including additional aluminium. It was therefore decided to supply 5 p.p.m. aluminium to all plants other than those reserved for investigation of the effects of different concentrations of this element. Improvement of leaf colour was noted three days after aluminium was included in the nutrient solutions, and the chlorosis entirely disappeared within a week.

RESULTS

No Nitrogen

The first symptoms were observed on Goliath ten days after nitrogen was omitted from the nutrient solution. King George, a slower growing variety, showed the first signs of starvation one week later. In both varieties the old leaves rapidly turned yellow, with red pigmentation along their edges accompanied by premature leaf-fall. Growth was extremely slow, the rest of the foliage remaining small and pale green.

Small but regular blooms were formed, maturing earlier than on the control plants. The colour of the blooms was pure blue for Goliath and mauve for King George.

No Sulphur

The omission of sulphur from the nutrient solution had little effect on the growth of the plants. At the time of flowering the old leaves were paler green than those of the control plants. Development of blooms was very slow, these maturing two to three weeks later than on plants grown with complete nutrient solution; this has also been our experience with all the flowering species we have previously investigated. Both varieties produced pink blooms.

No Phosphorus

Here again growth appeared to be little affected. In general the foliage was dark green, with red pigmentation in the old leaves at the time of flowering. Blooms were only slightly smaller than on the control plants, being blue in Goliath and mauve in King George.

No Potassium

Early and acute interveinal chlorosis developed on the youngest leaves. The veins remained green, but interveinal areas eventually became almost white (Plate 1). Very little growth took place, and at flowering

time the plants were only half the size of controls. At a later stage dark pigmentation appeared on the edges of the old leaves of King George. Flowering was slightly delayed, and blooms in both varieties had a poor pale-pink colour.

No Calcium

Development of the plants was uneven, some shoots making only weak growth with small foliage. The youngest leaves became somewhat chlorotic. The weak shoots produced only very small and loose blooms, pale in colour. Stronger shoots, on the other hand, produced normal sized blooms; individual flowers, however, tended to die early. In Goliath brown patches were noted on some petals. Flowering was slightly delayed, particularly in Goliath. Both varieties gave pink flowers.

No Magnesium

At first the effects of magnesium deficiency were not very pronounced, the plants attaining almost the same size as the controls. Later the symptoms of magnesium deficiency appeared suddenly. At the stage when the blooms were colouring a marginal chlorosis, followed by scorch, was observed on the older leaves of King George. By the time the blooms matured the foliage was badly affected and many leaves had fallen off.

In Goliath the symptoms appeared even more suddenly and spread with greater rapidity. The pattern was, however, different in this variety. Thus mild chlorosis of the leaves was followed by the appearance of irregular necrotic spots between the veins, these forming a characteristic ring some distance from the margin of the leaf (Plate 2). Both varieties gave pink blooms.

No Boron

The first symptoms were noted in the second half of April. The youngest leaves were narrow and thickened with a shiny crinkled surface (Plate 3). The growing points of the weaker shoots died before the flower buds appeared. Numerous side shoots subsequently developed, producing the bushy effect characteristic of this deficiency in many species.

When blooms were formed the individual flowers were badly affected. The petals were several times smaller than on control plants, their texture was rough and the edges were browned and dying (Plate 4). The shape and size of the petals was irregular, with unevenly distributed mauve colour in both varieties.

No Manganese and No Iron

There was no reaction to either of these treatments, the plants being similar to those grown in complete nutrient solution.

The effect of various levels of aluminium

Six different treatments were applied, the nutrient solutions containing 0, 4, 8, 16, 40, and 80 p.p.m. of aluminium. No attempt was made to counteract any acidifying effect of the aluminium sulphate used; in the absence of the latter salt the nutrient solution had a pH value of just under 6. The effects on foliage and flowers are described under their respective headings.

(a) Foliage

As previously stated, the complete omission of aluminium from the nutrient solutions resulted in chlorotic foliage, the leaves generally being pale green with very pale interveinal areas. Unlike the chlorosis resulting from potassium deficiency, which was very acute but confined to the younger leaves, the effects of aluminium deficiency appeared on all leaves without affecting their size.

Four p.p.m. of aluminium in the nutrient solution were sufficient to prevent chlorosis. Eight p.p.m. slightly darkened the green colour of the foliage, and still higher concentrations of this element produced a dull, dark green hue. A concentration of 80 p.p.m. in the nutrient solution caused browning of the leaves, and by the end of the experiment many of the older leaves had withered and fallen. Some browning and dying of the older leaves was also observed at a concentration of 40 p.p.m. although to a lesser extent.

(b) Flowers

The colour of the flowers varied with the concentration of aluminium in the nutrient solutions. Thus Goliath gave pure pink flowers in the absence of aluminium and almost pure blue flowers when 40 or 80 p.p.m. aluminium were present in the nutrient solutions. King George gave pink blooms at low concentrations of aluminium, but at higher concentrations the colour was mauve rather than pure blue. The sequence



PLATE 1. Chlorosis of a young leaf from a potassium-deficient plant, with a comparable leaf from a control plant on the right. (Variety : Goliath)



PLATE 2. Magnesium deficiency, showing brown necrotic areas on two fully developed leaves. (Variety : Goliath) A : Upper surface ; B : Lower surface



PLATE 3. The shoot on the right is from a boron-starved plant. Note the distortion and thickening of young leaves and the death of the growing point. (Variety: Goliath)



PLATE 4. The effect of boron-deficiency on the flowering of hydrangea. Control plant on the right. (Variety: King George)

of development of blue colouration in the various organs of the flower in relation to aluminium concentration was as described by Allen¹.

In addition to the effects of increasing concentrations of aluminium on the foliage and flowers, concentrations of 40 and 80 p.p.m. caused some stunting of growth. Some root damage was also found at the higher concentrations, accompanied by a tendency to wilt during sunny periods. The latter effect is probably related to the increased acidity resulting from the higher concentrations of aluminium sulphate. King George proved more sensitive to such injury than Goliath.

Discussion of results

From the present experiments it can be concluded that hydrangeas are very susceptible to nitrogen and potassium deficiencies but less so to shortage of phosphorus once the plants are established. The plants were far less affected by calcium deficiency than were other subjects previously studied in sand-culture. They suffer badly from magnesium deficiency, which can disfigure the foliage during flowering. The hydrangea is very susceptible to boron deficiency, both flowers and foliage being badly affected. In the present experiment the plants grew well without any additions of either iron or manganese ; it can only be concluded that at the low pH involved sufficient of these elements was dissolved even from the washed sand. A chlorosis of hydrangea leaves ascribed to iron deficiency, and readily corrected by treatment with iron-sequestrene compounds, is not uncommon in soil-grown plants under commercial conditions.

Iron was considered by several investigators to be of great importance in the nutrition of hydrangeas, and Allen¹ has proved conclusively that its omission resulted in chlorotic foliage and poor growth. He had, however, to use sand thoroughly washed with aqua regia in order to induce iron deficiency. Allen¹ also reported normal green plants in the absence of any added aluminium. This is contrary to our experience, as mild but widespread chlorosis occurred in all plants not supplied with aluminium.

The chlorosis of young leaves occurring when potassium was omitted suggests that the uptake or metabolism of iron was affected under these conditions. The relationship between these two elements has been studied by Wallace and Hewitt² and later by Hewitt and Bolle-Jones³ and Bolle-Jones⁴ ; their conclusions provide an explanation of the results obtained in the present experiments.

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APPENDIX "A"

PUBLICATIONS

1919

PAINE, S. G., and BEWLEY, W. F. Studies in Bacteriosis IV. "Stripe" Disease of Tomato. *Ann. Appl. Biol.*, VI, 183-202.

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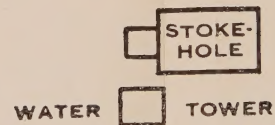
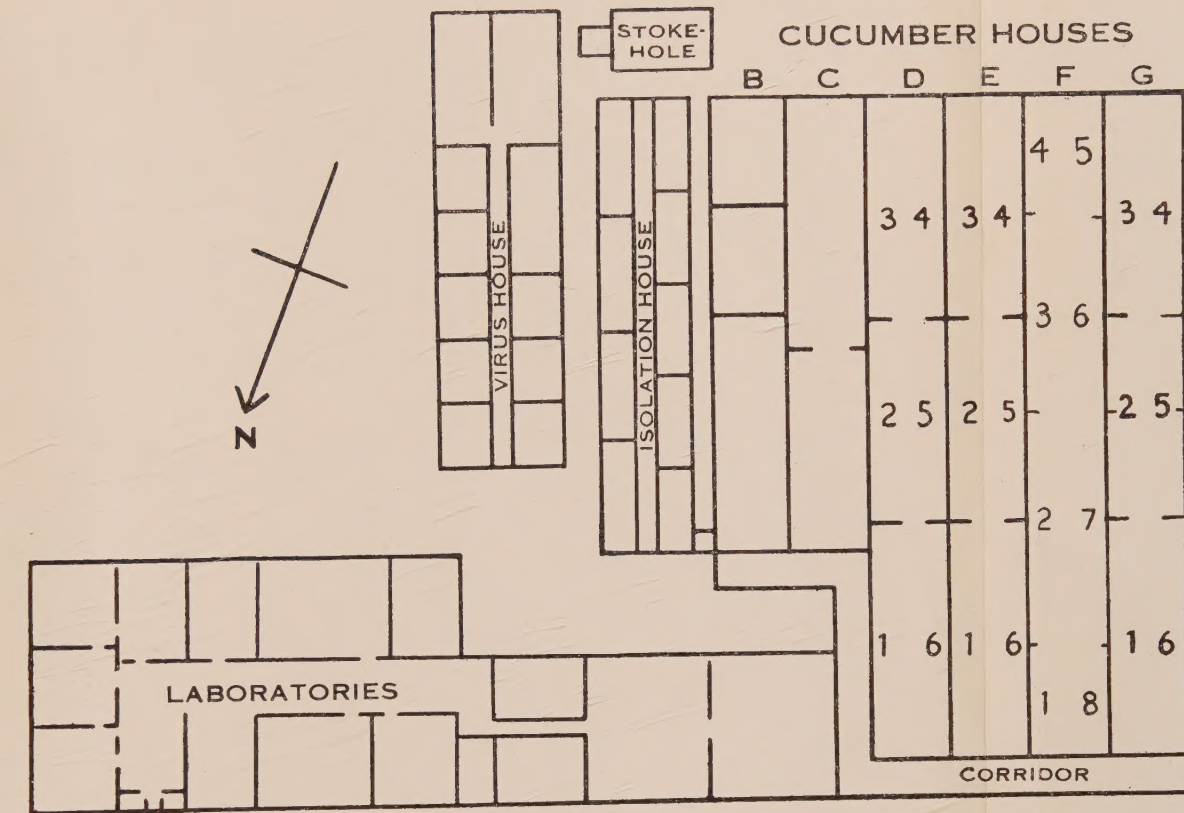
APPENDIX "B" **METEOROLOGICAL RECORDS, 1954**

Month	Air Temperature										Rainfall				Mean Soil Temperatures at 9 h. G.M.T.				Hygrometer at 9 h. G.M.T.				No. of days for 9 h. G.M.T.	Bright Sunshine																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																											
	Mean		Absolute Maximum		Absolute Minimum		No. of frosts	Absolute Grass Min.		Total ppt	No. of days with .01 in. or more	Greatest fall		Mean Soil Temperatures at 9 h. G.M.T.				Hygrometer at 9 h. G.M.T.																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																	
	Max.	Min.	Temp.	Date	Temp.	Date		Amt.	Date			°F	°F	°F	°F	°F	°F	°F	°F	°F	°F	°F				°F	°F	°F	°F	°F	°F	°F	°F	°F	°F	°F	°F	°F	°F	°F	°F	°F	°F	°F	°F	°F	°F	°F	°F	°F	°F	°F	°F	°F	°F	°F	°F	°F	°F	°F	°F	°F	°F	°F	°F	°F	°F	°F	°F	°F	°F	°F	°F	°F	°F	°F	°F	°F	°F	°F	°F	°F	°F	°F	°F	°F	°F	°F	°F	°F	°F	°F	°F	°F	°F	°F	°F	°F	°F	°F	°F	°F	°F	°F	°F	°F	°F	°F	°F	°F	°F	°F	°F	°F	°F	°F	°F	°F	°F	°F	°F	°F	°F	°F	°F	°F	°F	°F	°F	°F	°F	°F	°F	°F	°F	°F	°F	°F	°F	°F	°F	°F	°F	°F	°F	°F	°F	°F	°F	°F	°F	°F	°F	°F	°F	°F	°F	°F	°F	°F	°F	°F	°F	°F	°F	°F	°F	°F	°F	°F	°F	°F	°F	°F	°F	°F	°F	°F	°F	°F	°F	°F	°F	°F	°F	°F	°F	°F	°F	°F	°F	°F	°F	°F	°F	°F	°F	°F	°F	°F	°F	°F	°F	°F	°F	°F	°F	°F	°F	°F	°F	°F	°F	°F	°F	°F	°F	°F	°F	°F	°F	°F	°F	°F	°F	°F	°F	°F	°F	°F	°F	°F	°F	°F	°F	°F	°F	°F	°F	°F	°F	°F	°F	°F	°F	°F	°F	°F	°F	°F	°F	°F	°F	°F	°F	°F	°F	°F	°F	°F	°F	°F	°F	°F	°F	°F	°F	°F	°F	°F	°F	°F	°F	°F	°F	°F	°F	°F	°F	°F	°F	°F	°F	°F	°F	°F	°F	°F	°F	°F	°F	°F	°F	°F	°F	°F	°F	°F	°F	°F	°F	°F	°F	°F	°F	°F	°F	°F	°F	°F	°F	°F	°F	°F	°F	°F	°F	°F	°F	°F	°F	°F	°F	°F	°F	°F	°F	°F	°F	°F	°F	°F	°F	°F	°F	°F	°F	°F	°F	°F	°F	°F	°F	°F	°F	°F	°F	°F	°F	°F	°F	°F	°F	°F	°F	°F	°F	°F	°F	°F	°F	°F	°F	°F	°F	°F	°F	°F	°F	°F	°F	°F	°F	°F	°F	°F	°F	°F	°F	°F	°F	°F	°F	°F	°F	°F	°F	°F	°F	°F	°F	°F	°F	°F	°F	°F	°F	°F	°F	°F	°F	°F	°F	°F	°F	°F	°F	°F	°F	°F	°F	°F	°F	°F	°F	°F	°F	°F	°F	°F	°F	°F	°F	°F	°F	°F	°F	°F	°F	°F	°F	°F	°F	°F	°F	°F	°F	°F	°F	°F	°F	°F	°F	°F	°F	°F	°F	°F	°F	°F	°F	°F	°F	°F	°F	°F	°F	°F	°F	°F	°F	°F	°F	°F	°F	°F	°F	°F	°F	°F	°F	°F	°F	°F	°F	°F	°F	°F	°F	°F	°F	°F	°F	°F	°F	°F	°F	°F	°F	°F	°F	°F	°F	°F	°F	°F	°F	°F	°F	°F	°F	°F	°F	°F	°F	°F	°F	°F	°F	°F	°F	°F	°F	°F	°F	°F	°F	°F	°F	°F	°F	°F	°F	°F	°F	°F	°F	°F	°F	°F	°

* Grass Min. 30.4°F. or less.

† Visibility 440 yards or less.

DIAGRAM SHEWING ARRANGEMENT



ENGINE HOUSE

NT OF EXPERIMENTAL PLOTS, 1954

TOMATO HOUSES

